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ABSTRACT

To clarify the relationships among education, employment, and technological research, this study constructs a planning model based on these areas' component fields and their complex interrelationships. Emphasizing that little research has been done on the relationships of education and technology and that little understanding has been achieved of the patterns of technology transfers, the author sees the education system as an historical and socializing organism within which operate material, administrative, and pedagogical structures. The purpose of education, it is noted, is determined on the basis of the objectives chosen for the system at all levels--for the daily operational missions as well as for the broader educational goals. The movement towards more specialization, moreover, is characterized as preventing the formation of unified models of knowledge and fragmenting administrative organization in education. The system of technological production and dissemination is then analyzed in several aspects: its relation to scientific information, its transferring of information among sectors of society and between nations, and its administrative layers. The author sees the integration of technologies as a contribution to the growth of a technological culture and gives attention to developing countries' problems with the regulation and structure of spreading technologies. Concentrating finally on the central role of employment in bringing together systems of education and technology, the study concludes with projections for research into the relationships of the systems in the next century. (JW)

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IIEP research report: ㊷

INTEGRATING THE PLANNING OF EDUCATION AND TECHNOLOGY

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CONTENTS

Page

I. THE PROBLEM POSED 1

II. UNDERSTANDING THE TECHNOLOGY AND EDUCATION SYSTEMS 7

Caption to the diagram showing the relations between education, employment, science and technology 9

- A. Epistemological notes 16
- B. The state of research into education and technological systems 23
  - 1. Research into education 23
  - 2. Research into technology as a system 25
- C. Education as a set 27
  - 1. Education, cultural field, models of knowledge, cultural models 27
  - 2. The education system: reference points 31
    - (i) An historical, living, social system 31
    - (ii) Structural elements 33
    - (iii) Basic questions 36
      - (a) System of objectives 36
      - (b) The pedagogical model 39
      - (c) Disintegrating tendencies in the education system 44
- D. The "Science-Technology" set 46
  - 1. Science-Technology-Technique 46
  - 2. Structural elements 49
  - 3. Basic problems 59
    - (a) Debate on the state of the STS 59
      - (i) Thesis: the scientific-technological order 59
      - (ii) Antithesis: science and technology in fragments 60
      - (iii) Remarks 63
    - (b) Technological culture and education 66
      - (i) The integration of technologies 67
      - (ii) Technological culture 75
    - (c) Technology transfers 77
      - (i) The problems of the developing countries 86
      - (ii) Intermediate technologies 91
      - (iii) The regulation of transfers 94
      - (iv) The structure of transfers 96
- E. The sub-system of technology-education interactions 101
  - 1. The mediatization of employment and occupational tasks 101
  - 2. Identifying "nodes" in the interactive systems 108

III. PREPARING FOR THE 21st CENTURY 118

BIBLIOGRAPHY 124

I. THE PROBLEM POSED

The need for educational planning began to appear during the 1950s in the market economy and developing countries.

Three pressures simultaneously helped generate this need : demographic explosion, social demand for education, and the changing manpower requirements of growing economies.

But it was immediately obstructed by the absence of methodology, instruments and qualified personnel in the education administration structures. At that time only the USSR had any experience of planning education.

Although some farsighted individuals anticipated a crisis for education, that crisis could not be averted, and it took the form of spectacular explosions in a number of industrialised and developing countries.

Economic growth, the economic and social upheavals stemming from the revolution in science and technology caused, and are continuing to cause, an enormous problem in adapting the education system.

It has been throttled by the flood of entrants, too slow a pace of adaptation, lack of qualitative adaptation, and restricted outlets for its products.

The education system was not alone to blame for the wastage of human resources this led to. To take just one example, it was the socio-economic system which proved incapable of providing jobs for the young certificate holders, and of preventing the transfer of resources from poor to richer countries through the brain drain.

Educational planning has not, on the whole, been able to cope with the breadth of the problems.

The problems are known. Long term strategies to deal with them are indicated in the diagnostic works referred to in the footnotes below (1) and (2). These will be taken as our point of departure.

The exercise of social control over technology is a theme which appeared during the 1970s, born of dissatisfaction in the advanced industrialised countries with the social results of applying science and technology.

---

(1) Philip H. Coombs, La crise mondiale de l'éducation, PUF, Paris, 1968

(2) Edgar Faure and others, Apprendre à être, Unesco, Fayard, 1972.

The idea that progress in basic science must inevitably guarantee innovation ceased to be an article of faith. Future innovation itself ceased to be regarded as an aim which would always be socially or politically desirable. This reaction was felt by scientists themselves. For the first time, the positivism induced by the method and success of science was called into question by scientists. (3)

In the developing countries, the need for social control over the technology transferred from the industrialised countries was born less from an ecological reaction than as the manifestation of a political will to put an end to the unsatisfactory way in which interdependence worked for them.

It was also born of a reconsideration of the rules of the game for the International economic order.

The basic assumption of the "International Development Strategy" formulated towards 1970 by the United Nations System was that the development of the Third World would come about through integration in the world economic system. "But events have disproved this assumption. The integration anticipated has increased the dependence and reduced the autonomy of the developing countries to the extent that they have been induced to produce what was desired by the "international system" rather than what they themselves needed". (4)

The New International Economic Order contains the aspiration for a new international distribution of activities and employment.

To give concrete form to these aspirations "the traditional conception of economic exchange must be broaded and, indeed, go beyond the field of economics itself ..." similarly, "the very meaning of economic exchange experienced in a spirit of reciprocity, must be restored .(4)

The transfer and adaptation of technologies, together with their endogenous creation, enter into the new framework of a broader exchange.

In politics and political economy, good intentions are not enough. One must start from the realities if one wishes to change them.

---

(3) Jean-Jacques Salomon, Les études de socio-politique de la science et l'évolution des politiques, Seminar, "Peut-on rediriger la Science?"

(4) Le Monde en devenir, Réflexions sur le Nouvel Ordre Economique International, Unesco, Paris, 1976.

Contemporary reality is moving further and further away from "pure exchange", if the latter has ever existed. For pure exchange is concerned with "divisible goods, of which each unit is just like every other".(5)

Today the predominant form of exchange is composite exchange, i.e. a combination of free and reciprocal transfer of utility and power relations, logically expressing the economic relation which is essentially a form of conflict-cooperation, struggle-assistance . (5)

The economics of technology transfer must be reconsidered in the light of this concept.(6) Technology is power.

Nowadays, technical leadership is one of the major conditions for political leadership (7) The relations between the great powers are increasingly defined in terms of "technopolitics" rather than "geopolitics". (8)

The intrusion of science and technology into diplomatic politics has revolutionised it, producing the concept and methods of technical diplomacy (9)

The New Economic Order also implies a new technological order (10) less coercive towards the weak and more cooperative.

Technology imprints itself upon cultural models. The word "technetronic"(11)has been used to describe contemporary society, in which the impact of technology and electronics is manifested culturally, physchologically and socially.

---

(5) François Perroux, Pouvoir et économie, Bordas 1973

(6) Pierre F. Gonod, Conflit-cooperation dans le transfert technologique, Mondes en développement no. 14, 1976

(7) Henry Kissinger, Power and diplomacy, in The dimensions of diplomacy, John Hopkins Press, Baltimore, 1974

(8) See the article by E.E. David, former Science Adviser to the President, in the Wall Street Journal, quoted in the Journal Science, 25th August 1974

(9) Pierre F. Gonod, Clés pour le transfert technologique, Institut de développement économique, World Bank, August 1974

(10) Maximo Halty Carrere, Towards a new technological order ? Seminar, Science, technology and development in a changing world, 17th April 1975

(11) Zbigniew Brzezinski, Between two ages - America's rôle in the technetronic era, Penguin, 1976.

"The technological order" has hitherto been considered chiefly from the standpoint of philosophical criticism and conflicting values within society. (12)(13) No one would nowadays deny the acuteness of such conflicts.

The significance of the present-day "scientific and technical revolution" for marxism has been looked into deeply and some initial replies have been forthcoming (14)(15) from a differing standpoint, it has also been the subject of research programmes (16).

The present debate on "technology and man", while gaining in breadth, has not always maintained so high a level. "It involves the three classical characters: the detractor, who sees humanity doomed to the scientific apocalypse, the optimist, who ignores the "disillusionments of progress" and the sage, who thinks that from the stone age to the nuclear age, man can as easily use his tools to destroy as to build. There is little original in these repeated disputes". (17)

Yet, without coming down on any one side in the crucial matter of value conflicts, pressing social imperatives make it essential to go beyond the terms of this debate and try to tackle it both more systematically and more concretely. Only in this way can the demands of the new international economic order be met.

"The new international economic order is not a pre-established model which need merely be applied. It has to be invented, starting from the most legitimate aspirations of the peoples". (18)

The search for a new technological order forms part of this effort of imagination.

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(12) Jacques Ellul, La technique ou l'enjeu du siècle, 1954

(13) The technological order, Proceedings of the Encyclopaedia Britannica Conference, edited by Carl F. Stover, Wayne State University Press, Detroit, 1963

(14) "Techniques nouvelles, Sociétés nouvelles", special international research edition, September/October 1966

(15) Radovan Richta, La civilisation au carrefour, Anthropos 1969

(16) University of Harvard research programme on technology and society

(17) D. Furia, P. Ch. Serre, Techniques et sociétés - liaisons et évolutions, Armand Colin, 1970

(18) Forward by Mr. Amada-Mahtar M'Bow, Director General of Unesco, to the book "Le monde en devenir', op.cit. ref.4.

A new technological order would mean that the developing countries no longer regard technology as a datum, a simple means, but also encourage it as a development variable. Variable, too, in the sense that there is an alternative, an option not a de facto imposition. Variable also in the sense that it becomes an explicit target to be achieved, command over a level of knowledge and know-how sufficient to confer a certain degree of independence and satisfy self-determined needs.

A new technological order may be no less essential for the advanced industrialised countries, the "Centre". What is at stake is nothing less than the survival of the human race, or in less dramatic terms, simply to bequeath to our descendants a world fit to live in and to stop the wastage of non-renewable resources which must, whatever the reserves, come to an end one day.

Since the countries of the "centre" will long remain the principal source of science and technology, despite the progress hoped for the developing countries, the latter must rely heavily upon technology transfer in order to industrialise. Some effort must therefore be made to ensure that the unfavourable aspects are not transferred mimically at the same time.

With the end of "uncontrolled growth" the content, orientation of the development of the human resource must be redefined. Cultural models other than those which have led to a dead end must be found, not by expunging science and technology - which would, if it were possible, lead to a dissolution of society and cultural regression - but bending the creation and dissemination of technologies to redefined needs.

These gigantic tasks are easier to describe than to carry out, given the depth and force of the socially uncontrolled dynamism of technology.

The technological system is not an isolated artefact. It develops within complex interactions involving science, education, culture, the economy, society and its classes. What degree of relative autonomy does it possess ? What are its principal relations with other systems? What are the nature and characteristics of these relations ? Is there a link between the crisis in education and the absence of social control over technology?

These are the principal questions to which the present work offers some preliminary and, doubtless, very incomplete answers. They are considered successively, first the education side, then the technology side, and their interfaces.

The starting assumption was that among all the relations, those between the education system and the scientific/technological system should be examined first.

These relations are a key issue, yet have been very little studied.

The author has endeavoured to begin to untangle from this very complex web, the principal threads which may serve as a guide in mastering the development of education and technology in combination.

II. UNDERSTANDING THE TECHNOLOGY AND EDUCATION SYSTEMS

Analysis of the inter-relations between education and technology covers a very wide intellectual field.

We must start by trying to characterise them as systems, and elucidate their structures.

It is necessary to grasp the logic of their relations. Education is both a world in itself and a reflection of the world. It is shaped by the world, and helps to shape the world.

Science becomes operational through technology and is incorporated in production through a social process.

So it is also necessary to grasp the logic of that transformation, the conversion of scientific knowledge in production, and the social process of the creation and transfer of technology.

Lastly, we must understand the dialectic of the relations between the production of technological knowledge through scientific and technical research, and its reproduction through education.

Between education, which prepares men to perform an activity, and its exercise in production, stands the employment structure, which is itself part of the socio-economic complex.

The relations between education and technology should therefore be included as part of the network of relations with other systems : political, cultural, economic, social, demographic, ecological, individual, i.e. in a model of society of which they are the central components.

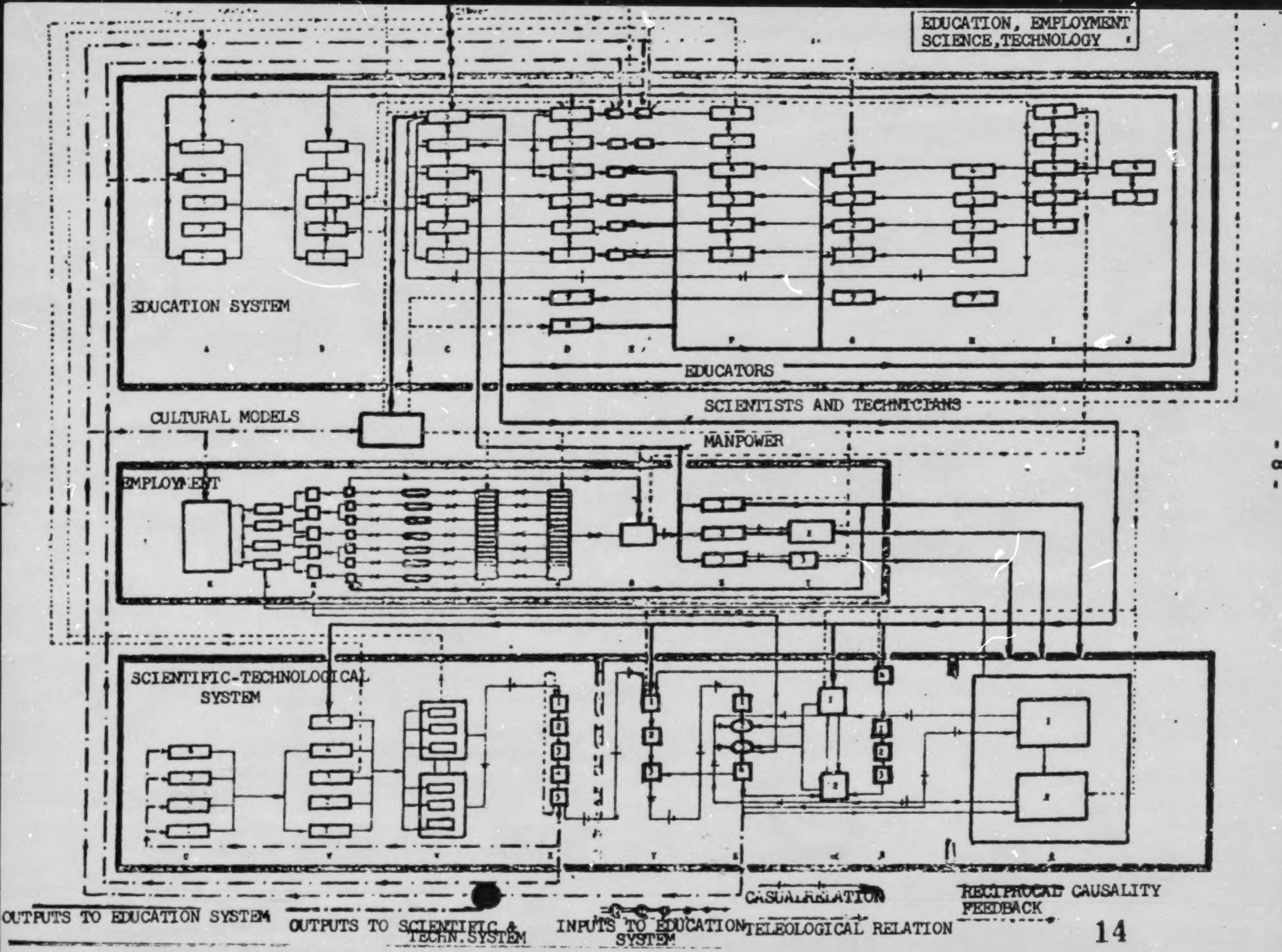
But while systems analysis is achieving progress, it is not yet at present in a position to present a model of mankind, nor a global model of society.

If such models existed, the present analysis would be to a large extent pointless, since most of the questions it raises would have already been answered.

There is consequently no alternative to trying, on the basis of accumulated knowledge, to construct a miniaturised model of the relations between education, science and technology, without losing sight of the principal connexions with the environment of other systems.

Even when limited in this way, the field of investigation remains considerable. A model summarises the synthesis made. The synthesis is supported by a number of works, of which the most important are shown in a selective bibliography in the annex.

The model is described in the diagram and captions below.


EDUCATION, EMPLOYMENT
SCIENCE, TECHNOLOGY
EDUCATION SYSTEM
A
B
C
D
E
F
G
H
I
J
EDUCATORS
SCIENTISTS AND TECHNICIANS
CULTURAL MODELS
MANPOWER
EMPLOYMENT
SCIENTIFIC-TECHNOLOGICAL
SYSTEM
OUTPUTS TO EDUCATION SYSTEM
OUTPUTS TO SCIENTIFIC & TECHN. SYSTEM
INPUTS TO EDUCATION SYSTEM
CASUAL RELATION
TELEOLOGICAL RELATION
RECIPROCAL CAUSALITY
FEEDBACK

CAPTION

TO THE DIAGRAM SHOWING THE RELATIONS BETWEEN EDUCATION, EMPLOYMENT, SCIENCE AND TECHNOLOGY

EDUCATION SYSTEM

Equipment subset

A 1 School premises and architecture
  2 School fittings
  3 school equipment
  4 educational technology equipment
  5 documentation

Administration subset

B 1 School establishments
  2 personnel
  3 personnel grades
  4 management of establishments
  5 Education laws, decrees, regulations

Pedagogical subset

C Education cycles
  1 nursery
  2 elementary
  3 1st school cycle
  4 2nd school cycle
  5 higher education establishments
  6 universities

D Teaching programmes
  1 nursery
  2 elementary
  3 1st cycle
  4 2nd cycle
  5 higher education establishments
  6 universities
  7 special programmes
  8 continuing education

E Curricula

F Teachers' training
  1 nursery
  2 elementary

  - 4 2nd cycle
  - 5 higher education establishments
  - 6 universities

G- Pedagogical research
  - 1 nursery
  - 2 elementary
  - 3 1st cycle
  - 4 2nd cycle
  - 7 special programmes

H- Evaluation
  - 1 nursery
  - 2 elementary
  - 3 1st cycle
  - 4 2nd cycle
  - 7 special programmes

I- Examination inspection of knowledge
  - 2 elementary
  - 3 1st cycle
  - 4 2nd cycle
  - 5 higher establishments
  - 6 universities

J- Orientation
  - 3 1st cycle
  - 4 2nd cycle

EMPLOYMENT

K- Nomenclature of professions and skills
  - L- Branches of activity
  - M- Enterprises
  - N- Specific tasks
  - O- Personnel status
  - P- Levels of qualification
  - Q- Salary levels
  - R- Job specifications
  - S- Job recruitment
    - 1 joining direct
    - 2 joining after specific training
    - 3 joining after supplementary training
  - T- Supplementary training
    - 2 specific trainings

SCIENTIFIC-TECHNICAL SYSTEM

Sub-set of scientific and technical research Equipment

U- 1 premises, laboratories
- 2 scientific instruments
- 3 calculating facilities
- 4 documentation

Sub-set of the Administration of the scientific and technological research system

V- 1 Administration ofthe scientific and technical research units
- 2 personnel
- 3 status of personnel
- 4 management, co-ordination of establishments and programmes
- 5 laws, decrees, regulations concerning research

W- Scientific and technical research institutions: Laboratories, research centres, institutes

Sub-set of scientific methodology

X- 1 observation
- 2 experimentation
- 3 modelling
- 4 deduction
- 5 new information and theory

Sub-set of the production and transfer oftechnology

Y- Technological research and development
- 1 technological inventions
- 2 technological development and finalisation
- 3 technological innovations

Z,αβγ Technology transfers

Z- Technology transfer mechanisms
- 1 technological content to be transferred
- 2 types of transfer
- 3 channels and arrangements
- 4 technologies transferred

αβ Technology transfer agents

α 1 technology emitters
- 2 technology receivers

β 1 intermediate agents in transfer
- 2 ditto
- 3 ditto
- 4 inventors

γ Production systems
- 1 technological modules and typological associations
- 2 technical subject levels

PRINCIPAL INPUTS AND OUTPUTS

Education system inputs (NB)

A- material inputs (materials, finance

C- pupils

E- scientific knowledge, methods, information

E- information on technological innovations

G- scientific research results

A_4-education technology materials

Education system outputs (NB)

C- Elements of the cultural models

C- manpower

C- scientists and technicians

C- educators

E and C - education technologies

D- concept and practie of continuous training

Outputs of the scientific-technical system (NB)

X- knowledge, method, information
X- scientific instruments
X- measurement instruments
Z- technology transfers and innovations

PRINCIPAL RELATIONS

1. Teleological relations: for example, the education system "tends" towards finalities, earlier phenomena are linked to future phenomena

(a) within the education system
equipment sub-set (A) → administrative subset (B) → pedagogical subset (C to J)

(a_1) within the pedagogical sub-set:
education cycles (C) → programmes, curricula (D, E); orientation (J)→ exams (I) → evaluation (H) → pedagogical research (G) → pedagogical training (H) → programmes and curricula (D, E); curricula (E) → pupils (C); educators (B_2) → pupils (C)

(b) within the scientific-technological system

equipment subset (U) → administrative sub-set (V) → research institutions sub-set (W);

(NB) Letters indicate input and output subsets.

technical inventions (Y_1) → development (Y_2) → technological innovation (Y_3); relations between Agents of the technological transfers (α, β); technology transfer Agents ($Z_{2,3}$); technological innovation (Y,Z) → level of the technical objects (γ_2); horizontal transfer of technology (Z_4) → innovation (Y_3) technological modules (γ_1) → level of the technical objects (γ_2).

(b) within employment

Employment-oriented training (T) — specific tasks in enterprises (N).

(d) between the scientific-technical system and employment

Production systems (γ) → activity branches (L); technology transfer channels and arrangements (Z_3) — enterprises (M).

(e) between cultural models and employment

cultural models → status (P) and remuneration (Q) of employment.

(f) between cultural models and the Scientific-Technological System ("STS")

cultural models → the system of technical objects (2) → technological research and development (Y); → technological transfers ($\alpha\beta$)

2 Causal (or order) relations e.g.: the education cycles succeed one another according to the ages of the pupils.

(a) within the education system

Between the various cycles (C), programmes and curricula (D,E) pedagogical trainings (F), pedagogical research (G), evaluation (H) exams (I) orientations (J); exams (I) on leaving towards employment (C).

(b) within employment

Tasks (N) → job specifications (R) entrants to employment (S) → supplementary training (T).

(c) within the scientific-technological system

Between the sequences of scientific method (X); between technological modules (γ_1) the levels of the technical object (γ_2) and types (Z_2) channels and arrangements for technology transfers (Z_3).

3 Reciprocal relations e.g.: scientific and technical knowledge orient the content of higher education whose activities, in turn, create knowledge.

(a) within employment

Between the list of professions and trades (K), branches of activity (L), enterprises (M) tasks (N) occupational status (Q) qualification levels (P) levels of remuneration (Q) job specification (R).

(b) between the STS and the education system

- between the production of theories (X_5), the model of knowledge, specialisation of scientific institutions (W), the production of knowledge (X).
- between the fragmentation of science (W,X) and technology (Y_3), the segmentation of higher educations ($D_{5,6}$ $E_{5,6}$)

(c) between the STS, employment and the education system

between scientific and technical production (W,X,Y), education programmes (D,E), the "production" of specialists ($T_{1,2,3}$), the defence of status and remuneration (P,Q), scientific institutions (W), exams (I), programmes and curricula (D,E), the training of scientists and technicians, scientific and technical production (W,X,Y).

4 Feedbacks: e.g education programmes affect the training of the educators but are in turn retroacted upon by the body of educators so constituted.

(a) within the education system

Staff (B_2) and personnel status (B_3) on programmes and curricula (D,E) and occupational training (F); exams (I) on programmes and curricula

(b) within the scientific-technological system

From scientific theory (X_5) and verification on the return to observation (X) and experiment (X_2). From technical objects (Y_2) towards scientific and technological research (W).

c) between the education and scientific-technological systems, and employment

c_1) from the scientific-technological system to the education system

from the status of scientific personnel (V_3) and of the scientific and technological research institutions (W to programmes and curricula (D,E).

c_2) from education to employment

from exams (I) to job specifications (R)

c_3) from employment to exams

from supplementary training (T) to programmes and curricula (D,E).

c_4) from cultural models to education

to teachers (B_2), university and higher education staff (C_6) special programmes (D_7), permanent education (D_3)

c_5) from employment to cultural models

from the various forms of training for employment (T_2,T_3) to cultural models

c_6) from employment to the technical system

from employment tasks (N) to technical invention (Y_1)

c_7) from education to cultural models

from exams ($I_{4,5,6}$) to cultural models

A. EPISTEMOLOGICAL NOTES

The complexity of the analysis of the "system of systems" constituted by the "education-science-technology" trilogy has made it necessary to draw upon certain epistemological concepts deriving from recent developments in systems analysis.

"System" has the usual meaning of "a set of interacting components".

This immediately raises two problems: (1) identifying the constituent components, and (2), the characteristics of the interactions.

"Structure" here "designates what is expressed by the arrangement of the system components, within the framework ofthe theoretical model chosen to study it with" (19)

Identification of the system components derives from empirical knowledge. A system component, empirically identified owing to its possessing a certain type of property, constitutes "a purely qualitative predicate corresponding to the declaration that a certain characteristic is instantiated". (19)

The components, thus defined by rules of equivalence, can be assigned to "reference classes" (19).

The number and nature of the predicates used in the functional definition of a component "will depend, in general, on the theory adopted, which ultimately means on the assumptions underlying that theory" (19).

The first question is therefore to decide at what level to situate the theory; next, what are the characteristics assumed to play a part at this level in the phenomena to be explained (19).

Having assigned the components to "reference classes", the next step is to introduce conditions under which a component may pass from one reference class to another. The movement of a component from one reference state to another (e.g. from emitter to receiver) is a function of the "extrinsic characterists" of the system (19).

In many systems, "the conditions under which components move from one reference class to another correspond to much more complicated processes, which bring in the charateristics of a number of reference classes. This makes it necessary to consider sets of classes, which can be called "sub-systems of interaction" (19).

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(19) P. Delatre, Système-structure-fonction, essai d'analyse épistémologique. Recherches interdisciplinaires Maloine Doin, Paris, 1971

Component interactions are ultimately reflected in relations between reference classes, and "such relations belong to three basic types: topological, order, or transfer" (19). In this terminology, transfer relations are identified with algebraic relations.

With these concepts, the data defining the system can be specified.

There are eight such data: 1: postulation of reference classes; 2: number of reference classes; 3: definition of each reference class (intrinsic and extrinsic characteristics); 4: number of components in each reference class; 5: axiom that the reference classes contain components; 6: declaration that there are relations betwen reference classes; 7: fundamental type of relation between reference classes (e.g. group, order etc.); 8: definition of the relations between reference classes (assembly of the intrinsic and extrinsic characteristics expressing such relations) (19).

It is possible, by reference to the all-embracing concept of system, to define that of structure.

The relational structure contains data 1, 6 and 7. Components are only present through mere declaration that they occur. (19)

The total structure of the theory system contains data 1, 2, 3, 6 and 7. The concept of function appears there, as does that of the factors intervening in the relations between components (19).

The total structure of the real system adds datum 4, concerning the information about the number of components in each reference class (19).

These three levels of structure, with their increasing information content, correspond to increasinly elaborate levels of knowledge about the arrangements of the components in the system.

It is essential to understand the structure of a system to anticipate how it will evolve. For it can be demonstrated that "the exhaustive theoretical system adapted to the description of the real system can only be anticipated, by extension, on the basis an understanding of the total structure of the real system at a given moment" (19). This consideration is particularly important in the case of the evolution of complex systems, or systems of systems, which applies to the great interactive education-science-technology-employment complex.

The present paper therefore starts from the identification, made in the major works quoted in the bibliographical annex, of components and sub-sets.

This preliminary identification makes it possible to establish a match with the concept of reference classes. By reference to the legend to the foregoing diagram, they are as follows:

Reference classes

- Education system: Equipment (A), Administration (B), education cycles (C), Programmes (P), Curricula (E), Pedagogical training (F), Pedagogical research (G), Evaluation (H), Examinations and knowledge testing (I), Orientation (J).

- Employment system: List of professions and skills (K), Branches of activity (L), Enterprises (M), specific tasks (N), Personnel status (O), Qualification levels (P), remuneration levels (Q), job specifications (R), Employee recruitment (S), Supplementary training (T)

- Scientific-technical system: Equipment (U), Administration (V), Institutions (W), Scientific methodology (X), Technological research and development (Z), Technology transfer agents (α) Intermediate agents of technology transfer (β), production systems (γ).

Having identified the reference classes, the next stage is to try to observe the relations between them, see their components, and reach an understanding of the system of systems interacting between education, employment, science and technology.

The model thus established comprises 29 reference classes (10 for the education system ten for employment and 9 for the scientific-technological system).

Clearly, this is a somewhat crude representation of an infinitely richer and more complex reality. Later analysis in greater detail should make it possible to disaggregate the reference classes into more specific subsets.

However, it would be misleading to refine the model without at the same time refining the characteristics of the reference classes and, in particular, the nature and fundamental types of relations between them.

However, even at the level of the simplified model, it has to be admitted that there are vast gaps in what is known about the intrinsic and extrinsic characteristics of each of the systems taken separately, and on the relations subsisting between the reference classes of different systems.

Side by side with what appear to be well established relations there are others which have hardly been studied at all, and others which have not been mentioned,yet can be assumed to exist.

Knowledge of the systems considered globally, is patchy. Knowledge of the education system is certainly more developed than that of the employment or scientific systems. The technological sub-system, through an apparent social paradox, is the least understood as a system.

At the level of the study of a system of systems, therefore, we have the constraint of a smaller common denominator of knowledge.

Although this approach may afford no advance beyond what the available information permit, it nevertheless has the advantage that it enables areas of ignorance to be identified, research programmes to be oriented more systematically, and hypotheses be suggested.

These hypotheses, together with the theoretical models chosen for study of the systems, the general framework adopted to articulate them, and their descriptive components, will be specified further ahead.

But in advance of the analysis, the conclusion can already be suggested that both for education and for employment, science and technology, it does not at present seem possible to achieve an exhaustive understanding of their system. While it may be possible to establish a relational structure approach for the education system, the same cannot be said for employment, science and technology.

In the absence of sufficient data, there is no question of an intimate understanding of the total structure of the real system for any of the systems considered. This bars the way to a more scientific approach to how they can be expected to evolve, or what "scenarios" we can suggest.

While conceding this barrier, we have however endeavoured to progress beyond partial analyses, and to escape the dilemma of having to choose between a precise, but usually unattainable identification of the relations, and merely stating that some undetermined relation must subsist.

It has to be admitted that not much is achieved by drawing an arrow to indicate some relation, or plotting some reverse action. The "feedback" concept is inclined to become a convenient, but ultimately not very enlightening rag-bag as soon as one wishes to draw out its implications as a basis for explanation or action.

An advance in understanding can be derived from the typology, simple though this may be, which outlines the principal forms of causality (20) (21).

Thus the following can be distinguished :

- the traditional causal relation: an anterior phenomenon A is the cause of a phenomenon B ($A \rightarrow B$).
- the final or teleological relation : a phenomenon A is linked in one way or another to future phenomena ($A \rightarrow B$).
- reciprocal causality, of which circular causality (pseudo feedback) is a special form ($A \leftrightarrow \longleftrightarrow B$).
- feedback, in which the system displays "international" behaviour, tending towards the realisation of a goal, which signifies the existence of mediating mechanisms between the action of A on B and the reverse action of B upon A ($A \rightleftarrows B$). In a sense feedback is teleological (20).

In the absence of a more elaborate methodology, this reasoning may be worth applying to the analysis of inter and intra system relations, since the systems considered have various finalities.

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(20) Y. BAREL - Prospective et analyse de systèmes. La Documentation française - February 1971

(21) W. BUCKLEY - Sociology and modern systems theory. Prentice Hall inc. ENGLEWOOD CLIFFS - New Jersey - 1967

This logical analysis is apparently simple, yet it raises many questions and often leads to the formulation of hypotheses.

In fact, when unable to understand the real total system, one seeks to discover from each relation encountered, some particular aspect of the behaviour of the total system. Research thus implies an act of abstract logic (20) (22).

Many of these hypotheses demand validation. And it is possible, if not probable, that in no country will a real system prove to match the pattern of the model presented.

It must be borne in mind that the systems being studied are social systems. This in itself means that they are linked in a variety of ways to other systems.

Political systems, for example, will be characterised by different degrees of structural differentiation, cultural secularisation, sub-system autonomy (23) (24). It follows that how strongly the political system, say, is coupled to the education system will vary considerably.

The finalisation of the education and scientific systems may create teleological relations wherever they appear in other contexts as causal relations.

The weakness of the scientific and technical systems in the majority of developing countries, their non reproducible (25) "a-structured" and "a-functional" character sometimes attenuate or cancel out some of the inter-relations. Often the scientific research system cannot be differentiated from that of higher education. Scientific output may be too weak to permit internal accumulation and sufficient memorisation, which are essential conditions if the research system is to reproduce itself.

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(22) This way of proceeding has affinities with the progression method C.P. Shcedrovitsky calls "method of constructing structural models", see Methodological problems of system research in general systems, Yearbook, Vol. XI 1966

(23) J. LESOURNE - Les systèmes du destin. Dallos économie, 1977

(24) C. Almond and Bingham Powell, Comparative politics, a developmental approach, Little Brow and Co., Boston 1966

(25) S. Thebaud - Les "systèmes" de recherche scientifique et technique des pays en voie de développement, Revue Tiers Monde, January-March 1976.

There are major structural differences among developing countries, even within the same region, with which a typology of scientific and technical infrastructure level can be drawn up (26).

The same applies, to a lesser extent, to the education system, which may lack certain sub-systems such as pedagogical research, or some of the components in the reference-classes, such as doctoral preparation in education cycles.

The representation of employment in the model has been simplified to the uttermost. It has been reduced to the most significant of the relations perceived between the education and scientific-technological systems.

For the model to be less incomplete it would have been necessary to introduce the systems of the demographic environment and socio-economic systems. But this would presuppose an understanding of the real total system.

Despite these limitations, the representation adopted leaves room for a number of socio-economic parameters to be included : the existence, or not, of occupational social groups and their reactive power on employment, etc.

The same applies to the scientific-technological system. Since science engenders technology, the continuum of scientific and technological creation is symbolised in the same framework. However, a broken line marks the separation of technology, which is subject to other processes than science in economic exchange.

Another broken line indicates the continuum between technology and production, and therefore, the economic system. The concept of "system of production" is a technico-economic concept, used in the unusual sense of the interface between technology, the product and the market (27).

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(26) Vladimir Davidov - En torno a la evaluacion del desarrollo cientific-technologico de los paises latino-apericanos - Academia de ciencias de la URSS - Problemas de la revolucion cientifico-tecnica - Ediciones Suramerica, Bogota, 1975

(27) Joan WOODWARD - Industrial organisations : theory and practice, Oxford University Press, 1965

Furthermore, the "research and development" operations efface, towards their outcome, the distinction between what comes under a production activity (28). Here the value of the "sub-system of interaction" concept identified above(19) can be appreciated.

The principal relations considered thus come to 92 in number (33 teleological relations, 15 causal relations, 24 relations of reciprocal causality and 20 feedbacks. This is not very many when one considers the complexity of the real world, but it is more than are dealt with in the specialist publications (29).

The aim of this work cannot be to achieve knowledge of the "total structure of the real system" but to prepare the way towards such knowledge. To advance hypotheses, whether they prove true or false, is to pave the way for data to be combined together at a later stage with which to define the systems and their structures.

If we try to analyse the interacting structures and systems of science and technology, education and employment, we may hope one day to master their evolution and open the way to regulating them.

B. THE STATE OF RESEARCH INTO EDUCATION AND TECHNOLOGICAL SYSTEMS

1. Research into education

A common feature of education and technology research is that it has appeared rather recently upon the scene. Prior to 1950, the very concept of educational planning was practically unknown in most parts of the world. In the early 1960s there was no good manual on educational planning. At the present time "there still exists no universally accepted definition and, a fortiori, no acceptable general theory" (30).

Perhaps no universal definition of planning is possible. It depends on the social context, and on whether or not the objective conditions it requires are present.

Education theory, "pedagogy", is at the heart of the education system.

And although it certainly contains a stable common core, this is enclosed within a network of historical and geographical variables. The variables are therefore a factor of evolution. Pedagogical theories, linked to history, change from one period to another, from one society to another. Their stability is further shaken by the destabilisation of cultural models.

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(28) J.L. Maunoury - Economie du savoir, Armand Colin, 1972

(29) In "L'économie du savoir", J.L. Maunoury describes 13 - principal relations between research, education and production (document cited ref.II)

(30) P.H. Coombs - What is educational planning ? IIEP 1970

Pedagogy is the discipline based on the behaviour of the teacher in education, which is now beginning to have its converse in mathesis, as a science which studies the behaviour of the pupil during his learning period (2).

Understanding of the dialectic of the interactions of pedagogy and mathesis or in other words, the processus of transmission and acquisition of knowledge, its emission and reception, is what would illuminate the logic of the education systems. But this does not appear to be within reach yet.

"We have psychological and sociological facts, pedagogical methods, more or less ideological and sociological doctrines at our disposal, but there is no good or bad pedagogical theory and in the present state of knowledge it would be impossible to construct one" (31).

The difficulties encountered in pedagogical research programmes are of two orders : the long time they take, and their fragmentation.

"Research of this kind takes a period of time, and for structures or analysis of behaviour, the period varies from four to nine years" (31).

Research, at least in the United States, appears to have been conducted along five avenues : input-output study, process study, organisational study, evaluation study, direct observation (32).

It has been the almost exclusive domain of the psychologist. Later support from other disciplines leads to a segmentation of research and a growing need for interdisciplinarity.

In a word, "what is known about the effectiveness of education is a first and short step towards meeting the (present) challenge ... there have been few consistent, positive discoveries of value to education policy" (33).

(31) L. Geminard, L'enseignement éclaté, Casterman, 1973

(32) Harvey A. Averch, Stephen J. Carroll, Theodore S. Donaldson, Herbert J. Kiesling and John Ancus : How effective is schooling? A critical synthesis and review of research findings in Donald M. Levine and Mary Jo Bane: The inequality controversy - Schooling and distributive justice - Basic Books Inc. Publishers New York 1975.

(33) William J. Platt - Research for educational planning - notes on emergent needs, IIEP 1970

In fact the fragmentation of research is probably the consequence of the absence of a problematics. "All pedagogical research requires the painstaking elaboration of a problematics"(31). And this is a by-product of a model, even an imperfect model, of the system.

So far as properly programmed research is concerned, one of the major themes, newly tackled, is characteristically concerned with "identification of the aims of education" (33). Critical assessment of the United States research programmes also brings out this need (32). The very need to define, or redefine, the aims of the education system provides a valuable pointer to its teleological essence.

The new importance attached to the need for research into the self-construction of the system as a paramount condition for self-reproduction, educational adaptation and innovation, is also an interesting tendency to note, with something to say about the functioning of the system (33).

The trend in research themes shows how problems and needs have shifted.

As a consequence of the revelation of the crisis in education and its relationships with society, the "critical points" investigated by research are, apart from the ultimate purposes of education, the reciprocal adaptation of the education system to the economic system, the internal effectiveness of education systems, and permanent education (33).

It is worth emphasising that there appears to be no research into the relationships between education and technology.

2. Research into technology as a system

Research into the history of technologies began before the second world war (34)(35)(36). Research into technical innovation is still more recent, the expression "technological tranafer' and investigation of this apparently going back no further than about twenty years. This kind of research has been heavily concentrated in the United States. It has been stimulated partly by the analyses of economists, who have highlighted the important contribution of technical progress to economic growth, and partly by the practical need to transfer "spin-off" from space and nuclear research, in particular, to the civil sector.

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(34) Ch. Singer and various authors - A history of technology - Five volumes, Clarendon Press, Oxford 1954-1958

(35) J.P. Usher - A history of mechanical invention - Harvard University Press, 1959

(36) Maurice Daumas, Histoire générale des techniques - PUF, 3 volumes 1962, 1964, 1968

Controversity over the existence of a "technological gap" between Europe and the United States has also encouraged investigation of innovation and technology transfer (37).

Over recent years, the political importance of technology transfer towards the developing countries has provided a major topic for reflection.

It was only from the 1960s onwards that new ideas appeared in the analysis of technology transfer (38) (39).

Research into innovation and technology transfer increased vigorously, particularly in the United States, which produced more than 2,000 titles just on the dissemination of innovation, mostly by sociologists, and there are doubtless several thousand dealing with technology transfer as a whole.

Despite this wealth of material, technology transfer remains "a poorly understood process" (40).

A critical review of all this work leads to the clear conclusion : "there has been a wave of articles on this subject, but research has not advanced significantly beyond the descriptive stage" (41)

There are many reasons for this shortcoming. The optimism of the 1950s and 1960s about the role of science in society encouraged hasty extrapolation from the transfer patterns for scientific knowledge to patterns going from technical creation to diffusion into production.

If the very transfer mechanism was poorly grasped, the nature and properties of the technology transferred were little analysed, the implicit assumption behing these patterns being the neutrality of the intrinsic characteristics of the technologies with respect to their modes of transfer.

The multidimensional character of technology transfers led to a proliferation of case studies by distinct disciplines. Sociologists, social psychologists and information specialists provided that heaviest research contingents.

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(37) OECD Technological gaps, analytical report, 1970

(38) Harvey Brooks - National Science policy and technology transfer National Science Foundation 1966

(39) E. Jansch - Technological forecasting - OECD 1967

(40) W.R. Kintner, H. Sicherman - Technology and international policy The crisis of wishing - Foreign policy research institute - Philadelphia Pensylvania 1975

(41) Devendra Sahal - The multidimensional diffusion of technology - Technological substitution forecasting techniques and applications Edit. H.A. Linstone and D. Sahal - Elsevier New-York, 1976

However, entire domaine were left practically untouched, These studies generally ignored the question of the very special market for technology. The decisive role played by the multinationals in technology transfer was practically left untouched. Only recently have the mechanism for technology transfer within the multinationals been analysed(42). Economists have generally taken little interest in these processes.

The incapability of the literature of the last few years to go beyond the descriptive stage in analysing technology transfer must also be explained by the absence of any general problematics. Technology transfers, like social transfers, require a more fundamental interpretation of the system. This interpretation implies the explicit reintroduction of power relations into the analysis (43).

C. EDUCATION AS A SET

1. Education, cultural field, models of knowledge, cultural models

Education may be defined as "the deployment of the means with which to train the individual for production research and education".(44) According to this conception, the input-output transformation process of education can be brought back to the entry of pupils and the exit of "products" distributed among these three functions.

Economic analysis permits a distinction between "products" according to their "degree of finish" : the "finished products" (graduates), the "sub-products" (those who complete their studies but leave without obtaining their certificate), the "semi-finished" products (those who leave without completing the cycle) and, particularly in the developing countries, those who leave before the end of primary education and usually return to illiteracy. Wastage (in the form of drop-outs and repeaters) enter into the measurement of the rate of yield of the education system. (28)

The function of education presupposes the dissemination of existing knowledge, old and new, considered as necessary to exercise the three functions of production, research and education. In this sense "education can be regarded as a procedure for the "reproduction" of knowledge, this term being understood ... as the reproduction at ideological level of existing economic and social conditions. In other words what is at stake is not just the knowledge necessary for production and its ancillary intellectual activities, but also knowledge geared to the perpetuation of the production relationships". (28)

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(42) Jack H. Behrmann, Harvey W. Wallender - Transfers of manufacturing technology within multinational enterprises

(43) P.F. Gonod - Nouvelles représentations des transferts technologiques- Mondes en développement No.20 - 1977.

(44) J.L. Maunoury, op. cit. 28

Education is thus a powerful stabiliser in the evolution of social systems.

This conclusion is shared by other authors, but for other reasons.

First, because the school "is the only system which acts in a fairly homogeneous manner upon the majority of the population" (31)

Next, because of the "dynamic of the education system itself, which has something in common with asexual reproduction ... teachers engender teachers ... the self-reproduction of teachers, and the constraints of a large organisation ensure, generation after generation, through the programmes and the teaching methods, stable dissemination of the science and culture of the society as perceived by the education system. (45)

But the education system is not only a stabiliser in the evolution of social systems, but also a destabiliser: "it is around this two-way dynamic that the links of the education system with the other sub-systems are organised". (23)

The education system would be only a stabiliser of social systems, and of production relations in particular, if it only supplied "products" destined for the economy, science and itself. But these are not its only "outputs".

The education system, at university level and below, contributes to the creation of the "cultural field" of society, and the most essential aspect of this activity is the constitution of "models of knowledge". (46)

These models renew our vision of the world. (47)

"In addition to this creation of knowledge another fundamental cultural role is played. A society, at the same time as it develops a praxis of knowledge, represents its creativity and elaborates a cultural model which orients its action upon itself".

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(45) J. Lesourne, op.cit. 23

(46) Alain Touraine - Université et société aux Etats-Unis, op.cit. ref. 12

(47) This is how systems analysis operates at present.

In the advancedindustrial societies, "where the action of society upon itself is powerful, this creativity is seized "practically" and it is science itself which forms the cultural model of the society" (46). More precisely, science and technology.

Thus, the education system appears to exercise several rôles. Although they do not have a monopoly, higher education and universities exercise, in the first place, a rôle of transforming scientific and technical information into models of knowledge, i.e. into structured cognitive information. Next, they have a role in contributing to the formation of cultural models which are "operated" - and revolutionised - directly within the advanced industrial societies by science and technology. Lastly, the education system at its various levels fulfils the role of disseminator of the new values of society.

The sub-system of interaction between culture and education can just as easily be a regulator as a deregulator. Cultural changes used, on the whole, to come about slowly and in depth. In the contemporary world the speed of change, the intensification of links between culture and education can just as easily be a regulator as a deregulator. Cultural changes used, on the whole, to come about slowly and in depth. In the contemporary world the speed of change, the intensification of links between the cultures of all groups, the incoherence of cultural systems under the shock of the upheavals in knowledge and society, characterise the cultural dynamic of today. (23)

The speed and breadth of evolution in cultural models and education systems may vary.

Regarded from this standpoint, the crises of education are not generally manifestations of immobilism. They may occur even when the education system is evincing ceaseless creativity. By its very contribution to the cultural models, the education system creates, the conditions for its own disruption. But those conditions are directly brought about by systems evolving much faster - science, and especially, technology.

The world of technical objects is, today, integrated into cultural models. They form a frame of reference for teacher and taught alike. The young child goes to school with an "intellectual field" (31) largely determined by the ambient reality of the world it lives in.

In a situation like this, intellectual inertia and other intrinsic factors may act as a powerful brake on the pace of evolution, but this is no longer the regulating role referred to above, or not in the advanced industrial societies. The function of the education system in the knowledge required to perpetuate the production relationships also obeys this two-way dynamic.

"The cultural model of a society is not the ideology of a managing class; it is an essential element of the cultural field in which class conflicts form, and the opposing classes struggle to appropriate the cultural model, just as they do for the means of production". (46)

It is not the purpose of this report to treat or discuss the complex relations between cultural model and cultural field and ideology. These relationships are in any case highly controversial. At the risk of simplification, it may just be observed that in this conception, the cultural field and model belong to the whole society. But the cultural field envelopes the model. And because it belongs to the whole of society and, in turn, regulates society, the cultural model is the locus, and the stake, for the class struggle.

Thus the education system, the teachers, and more and more precociously these days, the pupils, are not passive elements in this conflictual field. They are involved in it.

This being so, we need not be surprised that the ultimate purposes missions and aims of education are subject to dispute, even within the teaching body, and that the pedagogical model to be deployed leads to confrontations, which are not always disputes between cliques but may reflect radically different conceptions of the aims to be attained.

Thus, teachers may come to challenge or reject a strictly economic purpose for education.

The pupil entering the education cycle cannot be regarded as raw material to be worked up for some predetermined use.

"The pupil is a human being ... one does not form him, he forms himself and in doing so, intervenes as an element in the undertaking... he develops in a social and family environment as well as in the educational environment". (31)

The pedagogical debate is ultimately a debate about finalities. Mathesis can be regarded as the converse, or the other side, of pedagogy; it implies a profound revision of education science : the learning process is tending to assume more importance than the teaching process. (2)

Beyond changes in the way in which education is actually performed, the less unequivocal relations between educator and student, the constant to and fro envisaged, from the humble, creative movement imposed upon educator and pupil to the liberating experience of school opposing the home experience (48) more is at issue than mere changes in pedagogical technique: new attitudes and human relations are being forged.

The relations between the education system, knowledge models, cultural field and cultural models of society are therefore highly complex. They will vary from one society to another, according to (a) the degree to which science and technology have penetrated cultural models (b) what the education system concerned contributes to the formulation and dissemination of the knowledge model (c) what the country's own scientific system contributes to the cultural model, and the proportion of transfers from other societies (d) the relative autonomy of the society's systems, the degree of cultural secularization (49) and political culture, the degree of social consensus towards the education system. These parameters are complex but they are not impossible to grasp. They should be identifiable with indicators designed for the purpose.

2. The education system: reference points

We need not here offer a description of the education system, for it has often been described already, sometimes from a systems analysis standpoint. (50) Here we need merely look at some reference points which may help us to get our bearings in the analysis of the education-science-technology system of systems.

(i) An historical, living, social system

Education is an "historical system" (20) which has had an ontogenesis.(31) Its history weighs upon its present; despite evolution, change and upheavals, some vestiges of its history remain.

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(48) Paulo Freire - Quelques idées insolites sur l'éducation - Document de la Commission Internationale sur le Développement de l'éducation - Opinion no. 36 - Unesco, Paris 1971

(49) Process by which individuals become increasingly rational, analytical and empirical in their political action (G. Almond and Bingham Powell, op.cit. ref. 24)

(50) See in particular L. Geminard, op.cit. reference 31

But whatever their specific features, whatever the configuration of their components parts, education systems present common and stable extrinsic characteristics, in space if not in time.

(1) The relations between their elements are teleological. The disrupted consensus over the aims of education in certain advanced industrial societies should not blind us to the fact that the disagreement is about what the aims should be, not whether there are such aims.

(2) The relations between their reference classes (19) are order relations.

The constant of the system is that education cycles succeed one another according to the age of the pupil. There may be changes in the way education is divided up into cycles, but the succession of cycles remain. Education is a "process of irreversible operations".(28) The notion of temporal order and sequence is so evident that it can be used to establish educational algorithms. (51)

(3) The relations between emitters and receivers of education are not transfer relations in the algebraic sense.

The transmission of an item of educational information and its assimilation by the receiver do not impoverish or empty the class from which the emission goes out. "The stock of knowledge does not deteriorate through use ... each unit of knowledge may be infinitely divided or reproduced without undergoing any alteration." (28) (52)

(4) Education, when re-examined in the light of information theory, appears as a process of forming and modifying "representations"

The latter are synonyms for an individual's "intellectual field" (31), a category which corresponds to that of "cultural field" (46) for society. "Representations" means any structure (model, image, etc.), abstract or concrete, whose characteristics symbolise or correspond in one way or another with those of some other structure. (53)

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(51) L.N. Lands - Algorithmization in learning and instruction - translated from the Russian - Educational technology - Englewood Cliffs N.J. 1974

(52) As we shall see, technology transfers also have an identical characteristic

(53) D. MacKay - Information mechanisms and meaning - MIT Press, Cambridge Mass. 1969

Information may be defined as that which is added to a representation.(53)

The effect of a unit of information is a change in the representation. Information forms or transforms representations.

Assimilation is a structural plasticity in forming and transforming representations. Learning is at bottom the observation and memorisation of information which one has "lived". The gradual nature of learning creates a succession of interiorised representational framework. (54)

(5) The systems reproduce themselves. As has been noted above, teachers engender teachers. Educators create their own pedagogical methods. The relations obey a circular causality. The methods of knowledge transmit themselves and ensure the stability of scientific concepts, philosophical categories and ideological notions (55) until they are replaced by other models.

(6) The education system, nothing less than a "communications crossroads" with all the other systems (23) can only undergo any major pedagogical change if it receives an impulse from outside (31), but so deep-seated are its self-reproduction mechanisms that for any such change to be effective, it must also be "operated" from within. This proposition can be reformulated in negative terms: the education system cannot be operated upon solely from outside, or solely from inside. Its reform requires a combination of external and internal forces. (56)

(ii) Structural elements

Education is an "historical" system and as a technical system, it is built up according to a technological structure. (31)

This will be more or less coherent according to the degree of structural differenciation and cultural secularisation of the political systems, which will leave a wider or narrower margin of autonomy to education systems. Political and education systems, cultural models and ideologies may be strongly coherent or more loosely connected, conferring a greater or lesser degree of stability upon the societies concerned. The scientific and technological systems, will be more or less organically linked to education, penetrating more or less deeply into the cultural model and, thence, the education system. In an overall society whose sub-sets are comparatively autonomous, the education system will be built up mainly on a self-organisation basis. Its components will therefore be arranged polymorphically. However, amid all this variety, some relatively constant technological operating structures can be distinguished. These are : the material structure, the logical lay-out structures formed by an administrative structure, and a pedagogical structure. (31)

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(54) These questions will be discussed again later on

(55) A. Badiou - Le concept de modele - Maspero 1972

(56) This explains the rather disappointing achievements of educational planning in the 1950s, which focussed exclusively on the overall parameters of the education system viewed from outside, ignoring its internal behaviour (See P.H. Coombs, op.cit. ref.30)

In addition to these may be added the structures of relationships with the environment and those favouring an explicit self-construction of the system. (31)

These latter structures work in very different ways from one national system to another, and do not appear as such in the "education-employment-science-technology" model but as functional relations of the components. Similarly, so as not to create confusion with the strict sense of "rational structure", "total structures of theoretical and real systems" (19) we have preferred to designate the "structures" corresponding to equipment, administration and pedagogy as "sub-sets".

These sub-sets form "reference classes" comprising elements. (58) Since the latter are well known, only the most important aspects need be discussed here.

"The system is in the first place, and this is too often forgotten, a vast administrative machine, with all the problems this entails" (23)

In many countries, education has become the largest branch of the economy, and the ministry of education the largest undertaking. The education system is structured according to two supplementary organisational principles : vertical and horizontal organisation. (28)

Vertical organisation is the outcome of a constant constraint: "the education process takes time, and is aimed at individuals who are evolving rapidly: children, adolescents, young adults. A fundamental principle of education is to harmonise the pace of transmission and the content of knowledge with the pace at which the pupil develops, mentally and psychologically". (28)

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(58) See the legend to the diagram for the relations between education-employment-science-technology.

Horizontal organisation applies to the arrangement of studies for a given standard age.

"Education is everywhere becoming increasingly specialised as the pupil advances in the field of scholarship which he has chosen for better of for worse, i.e. as he approaches the profession or occupation for which it destines him" (28)

This complex system, offering possibilities for choice, both vertically (length of schooling and different cycles) and horizontally (number of branches or streams, lay-out of programmes and curricula at each level and stream) has a functional logic. (31)

A first functional level corresponds to the intrinsic relations of the elements within the subset of which they form part.

A second level corresponds to the relations between sub-sets.

A third level is that of relations between elements belonging to different sub-sets.

A fourth level is that of the correspondence relations between intrinsic characteristics, the objectives of the social elements of the system (teachers, pupils, institutions) and extrinsic characteristics, the aims of the system itself.

This applies to the *internal* functional levels.

The functional logic of the education system implies an *integration* of elements in sub-sets, of sub-sets within themselves, of elements which are functionally related within different sub-sets, and of parts with the whole at the level of objectives and aims.

Clearly, the integration of the different education systems is more or less coherent, harmonious, complete and effective, not only according to how well the systems are integrated into the society but also depending on the sociology of the educational institutions themselves.

This raises the problems common to every large bureaucratic organisation. In particular, inadequate integration often shows through, as cause and effect, in the segmentation of the elements in the central administrative sub-set, the creation of "esoteric boxes" where each group has its own organigram, budget, underlying principles, doctrine and style of administration. (30) The institutions - social armistices - harbour rival fiefs which co-exist by means of a tacit non-agression pact.

Though these problems are not to be underestimated, the main cause of the tendency for the system to disintegrate is the increasingly specialised nature of the teaching, a question to which we shall return later on.

Certain other causes operate in the same direction.

Inadequate integration of the whole and its parts, hazy ideas about the purpose of education, imprecise objectives, the absence of research centres and reflection about pedagogy and pupil aspirations, or the dividing up of such reflection by educational level, the very logic of a system which interiorises a proportion or its outputs, encourage fragmentation on the one hand but also the "professionalisation" of education (59) in the sense that it becomes the exclusive affair of teachers, mandarins and educational castes.

An insufficiently integrated system will, through various feedbacks, seek zones of equilibrium at the level of sub-system elements, but the partial equilibria thus achieved may be at odds with the attempt to bring the whole system into equilibrium.

The system is in internal equilibrium (60) "when at a given moment, the distribution of pupils at all levels, in cycles and streams, is such that the educational phases for subsequent years (i.e. until pupils present at the moment of observation have finally left) can be pursued in such a way as to achieve the pedagogical objectives in view". (28)

But the main problem is to define these objectives.

(iii) Basic questions

The many questions raised about, and by, the education system regarding itself and how it fits into society can perhaps be subsumed into three major themes: system objectives, the pedagogical model, and the tendency towards disintegration.

(a) System of objectives

The setting of integrated educational objectives, "appropriately hierarchised, stated in operational terms, specifically adapted to the surrounding conditions, the characteristics of the communities or identified population groups" is a basic requirement for "education strategies" (2).

But there is a very big step to be taken between stating the principle and putting it into practice.

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(59) Yvan Illich - Une société sans école - édition du Seuil - 1974

(60) The concept of internal equilibrium must be distinguished from that of external equilibrium, which involves any discrepancies occurring between supply and demand for those educated.

Not only must the ultimate purposes be clear, but it must be possible to break them down into operational missions - the goals, and these must be specified in terms of evaluation criteria, together with a level to be achieved within a determined period - the objectives as such (61).

A hierarchised objective-system thus comprises three levels : the ultimate purposes, the goals, and the objectives.

Because the ultimate purposes express the rationales, ethical and sociological vocations, they are not directly operational. "Learning to be" summarises a whole conception of the ultimate purpose of education in society.

An ultimate purpose is not susceptible to demonstration. It has to be chosen and declared. It is the outcome of a general consensus (31) itself deriving from the cultural model and the place of cultural secularisation in political decision-making.

But the ultimate purpose or purposes chosen must then be "transformed" into operational orientations.

Here are some examples.

In France, after the crisis of May 1968, a start was made on the very general ultimate purpose of "compensating for socio-cultural handicaps". (31)

But merely to state this does not suffice for the determination of missions, still less for the setting of objectives by cycle and form of teaching.

Thus it affords no direct answer to the question whether "educational provision between the ages of 3 and 18 years should be designed in the first place as a system for continuing orientation or whether it should distribute pupils as soon as possible into oriented streams?" or again, "whether secondary education as a whole should provide the balanced formation of all the dimensions of the individual ? ... leaving higher education to deal with some parts of the content of disciplines at present taught, or should it put more emphasis on the study of discipline content and leave the greater part of physical and artistic development to the world outside the school?" or lastly, "whether technical education should prepare directly for employment, simultaneously dispensing professional competence and performance skills, or .... provide skills in mathematics, languages and the human sciences to enable the student to pursue his education further?" (31)

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(61) J. Melese - La gestion par les systèmes - Edit. Hommes et Techniques - 1969
See also: L'analyse modulaire des systèmes - Editions Hommes et Techniques, 1972.

So it is not just the ultimate purposes or the objectives which must be determined, but an objective-system.

Analysis of the logical relations within a collection of given objectives sometimes affords an insight into the really basic objectives which govern all the others (62).

A new intellectual and action method currently being worked out no longer separates examination of objectives from that of the action variables.

"The more we advance in understanding the parameters which define a field of action, the less we need to be rigid in our definitions of a problem, and the more capable we become of accepting that means should not be separated from ends, and that the most rational approach is the view which compares combinations of ends and means". (63)

It is by breaking down the action variables, i.e. the levers at the disposal of the operator, into decisional variables, decisional influence variables and constraints (64) and analysing how they relate to the objectives, that we can in practice achieve such a comparison of ends and means and, in many cases, identify the actual objectives of the whole.

In these circumstances the setting of objectives would itself be a factor for change, as it would imply broad participation at all levels of education and debate with the outside world.

Ultimately, the systems nature of education, its internal teleological relations, create a more vital need than elsewhere for an explicit orientation of the system.

Its complexity, its functional logic, its various levels of integration create the objective need for a hierarchised and coherent system of objectives. The deep-seated nature of its self-constructing and self-reproducing mechanisms make it necessary for the teaching body to be involved in defining this. The crossroads which it constitutes, the inputs it receives, the outputs it produces, its insertion in society, are such that its ultimate purposes and missions cannot be defined on an inward-looking basis by the education system alone.

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(62) P.F. Gonod - Propositions pour la planification scientifique et technique au Venezuela - CONICIT, Caracas, Septembre 1975

(63) Michel Crozier - La société bloquée - Editions du Seuil, 1970

(64) P.F. Teniere-Duchot - Une tentative d'analyse du système "eau" dans une agence financière de bassin - Futuribles, February-March 1973

(b) The pedagogical model

The second major problem confronting the education system is to work out its own pedagogical model. This problem derives from the foregoing problem.

A pedagogical model implies a definition of the extrinsic relations of the system in terms of ultimate purposes, goals, and objectives, and intrinsic relations between reference classes and elements.

Different models are therefore conceivable, either through evolution within the framework of the total structure of the existing real system, or through change in the latter.

Structural change is a new arrangement of the elements implying change in their intrinsic relations, made possible by the elimination of constraining relations. Hence the need to distinguish carefully between constants and other constraints (21).

A constant is a property of the system which will always be observed whatever changes may occur (for example, school age, education sequences) and which differs from a constraint in that the latter can be eliminated (for example : segmentation in the administrative machine, the volume of resources allocated to education).

In fact, structural change implies transformation of constraints which are not constants. In this sense the aim is to negate, or destroy the constraint. (20) Adaptive systems "transform" some part of the variety of environmental constraints and integrates them into their organisation under a structural and informational form (21).

Control over structures, evolution or deeper change is only possible if the total theoretical and real structures of the system are understood. A pedagogical model would be the finalised projection of these.

This raises the question of what currently prevents us from understanding the structures? The answer is at the level of the pedagogical sub-set.

Among the necessary data for determining the structures of a system (65) what especially appears to be lacking is sufficient knowledge of the data groups 3 and 7 (intrinsic and extrinsic characteristics of each reference class, the fundamental type of relations between reference-classes) within the pedagogical sub-set and in its internal and external relations to the education system.

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(65) See under A. Epistemological notes, p. 18

Which leads to the discovery that there is no pedagogical theory (30) (31). As a result, the resulting model of knowledge is inadequate for the construction of a pedagogical model.

Pedagogical research is, therefore, the action variable capable of overcoming this constraint.

"The objectives cannot be defined within the frame of reference determined by the ultimate purposes unless analysis of the system can be conducted with the support of pedagogical research exercises" (31).

The constraint can only be surmounted by creating a superior "variety" for the decision-makers, the condition for a higher degree of cultural secularisation. Despite its limitations, pedagogical research has made progress. It has been able to draw upon scientific contributions in biology, neurophysiology, basic brain research, social psychology, linguistics, semiology, anthropology, information and cybernetics (2).

Where are the "strong points" and "weak points" in these contributions ?

More substantial progress would appear to have been achieved and more so in understanding the psychology of early childhood, whose interpretation has produced a battleground for educators (2) than in understanding adolescent psychology.

The problem can be pinpointed like this : "no pedagogical theory can be inferred from the present state of scientific psychology for the 15-19 years age group" (31).

The psycho-pedagogy of adults is still less understood, since research has seldom gone beyond adolescence. (2)

The pace of progress for pedagogical theory is therefore dependent upon progress in fundamental scientific knowledge, which is therefore a constraint. But it is also a social imperative to set scientific priorities.

There is no single scientific road, a number of different avenues must be followed up. A great deal of progress "in linguistics, information theory, semiology, cybernetics, operations research and systems analysis have been little drawn upon by pedagogical theorists; yet it is perhaps these which would permit a proper approach to the study of education systems and a perspective upon them".

Hence the conclusion that despite these difficulties, the problem of constructing a theory could be posed. But this implies the formulation of successive "pre-models" of the system with which to provide an overall grasp of the problem and a basis for the interdisciplinary combination of research teams (66).

The problem is not therefore insoluble for all time.

The absence of evaluation for higher education results is associated not only with the limitations in scientific knowledge mentioned above, but also with a sociological phenomenon.

The precise definition of objectives would provide a basis on which to assess whether education was functioning properly. This would represent "half of the change to be brought about in education" (30). So long as the pupils remain within the school circuit some kind of evaluation, good or bad, is made. But once they have left they are no longer subject to any such testing. And it is what happens to the pupils when they leave that is "the real touchstone in appraising the contribution of the education system." (30)

The further one goes up in the education cycle hierarchy, the closer one approaches its outlets, the less evaluation is applied to what is being taught.

Since many education systems continue to have an elitist structure, the "élite" escape an evaluation which would be liable to be a self-criticism of their own self-reproduction.

The obstacles to be overcome are not only scientific in nature, they are most of all sociological.

Another key point in the formulation of the pedagogical model is a better understanding of the transmission and reception mechanisms for pedagogical information.

Here too, advances in information theory open up the prospect of important developments for pedagogics and mathesis.

The process by which knowledge is transmitted and acquired can be improved. And with such improvement, the human brain can mobilise what appears to be under-used potential. Perhaps this broadening is linked to that of the "intellectual field", i.e. of successive "representations".

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(66) On "interdisciplinarity", "multidisciplinarity", "pluridisciplinarity" and "transdisciplinarity" see Erich Jantch: "Towards interdisciplinarity and transdisciplinarity in education and innovation", OECD Seminar, Nice, September 1970

We have established that information is that which is added to a representation, and brings about a change in its construction (67).

Information can be analysed according to its content, selectively, structurally and metrically (68).

The selective content of information is the difference between the results observed after reception of the signal and the number of possibilities resulting from the initial representation of the receiver.

The structural content of information is the number of differientiable groups in the representation.

The metric content is the number of elements giving the model its weight or density - the "matter" out of which the "structure" is formed (68).

These discoveries are of great importance for the processes of assimilation, both for education and for technology transfer. A subject always possesses some "pre-fabricated elements of representation".

Selective information is that which has the power of modifying the previous configuration of the representation.

It is possible that in the past, most items of cognitive information had a selective power, as the school constituted practically the only channel for pedagogical information.

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(67) The basic research by MacKay has apparently been unknown to pedagogical specialists concerned with the concept and processes of "representation" in education. (See especially J. Migne, Etude des représentations de quelques notions de physique, INFA, 1967. Le concept de représentation et son rôle dans une pédagogie des connaissances scientifiques, INFA 1969). Bringing the disciplinary fields together would probably promote cross-fertilization and perhaps open new avenues for research.

(68) The processes by which portraits can be reproduced, in black and white, then colour, from computer analysis of the structure and quantity of the information contained, confirm and illustrate the discoveries of Mackay. Research at Bell Labs and by Leon D. Hamon at CASE Western Reserve University has led to a fuller understanding of the processes of perception and recognition by evaluation of the quantity, spatial distribution and rate of change in the factors causing them. Thus, for example, portraits of Lincoln and Jefferson can be broken down into 228 squares (structural information) each containing a quantity of information, each colour component being measured (metric information). The images thus obtained (block portraits) are sufficiently meaningful to be perceived and recognised (see Computer - IEEE July 1976, and J.L. Lemoigne - Les systèmes d'information dans les organisations - PUF 1974)

This is no longer so today. With the information revolution, now that information is carried by all the media, radio, television, film, records, human mobility, the environment of technical objects at all ages and school cycle levels, the content of representations have probably changed.

Similarly, this invasion of images doubtless reduced the selection power of educational information which no longer has the same additive property to previous representations.

This would tend to confirm the theory that the future task of education will be more one of "learning to learn", both at school and over one's whole lifetime.

The hypothesis might also be advanced that educational information is increasingly broad and diversified, loaded with an increasing metric content, and with less and less structural content.

This trend is due partly to the structural diversification of society, but mostly to the "disintegration of knowledge "arising out of the fact that as science advances it specialises more and more narrowly. (69) As we shall see, society's controls, as mediated by employment, are moving in the same direction.

Consequently, while other information media may partly take over the function of knowledge transmission, the school system, accentuating the avalanche of information, is less and less capable of procuring information with a high structural content which makes it possible to organise the total amount of information received. (70)

It is information which is sufficiently meaningful for perception and recognition which not only enables other information to be interpreted but also helps to eliminate non-significant information-noise.

The depth of the "intellectual field" is probably a function more of identifying the groups which structure information than of the elements densifying it.

These observations are of particular importance for technical instruction.

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(69) The matter will be discussed further on; to this thesis there is an antithesis.

(70) One example of information with a high structural content is the new approach to the teaching of modern mathematics.

They imply that technical education must be rethought, opening up intellectual fields by new combinations of knowledge having a high structural content, incorporating groups of basic knowledge which will be significant for all technologies.

They should also be brought to bear upon the ways in which educational technologies, especially audio-visual, are applied. For if it is true that their metric content is lower than that of reading (71), then the aim should be to use them as a means of imparting information with a high structural content, or at least with sufficiently significant groups to stimulate an intellectual effort permitting a "structural integration of high level" (31). This would orient education towards assimilation of the structure of the object. (72)

(c) Disintegrating tendencies in the education system

Persisting absence of general consensus in certain advanced industrial societies, together with socio-pedagogical crises would appear to threaten the education system with dislocation. More precisely, to lead to provisional outcomes in the setting up of separate micro or medio-systems.

The single system has already begun to totter with the setting up of parallel networks. Possibly all these will converge at some time in the future to form a global educational process, but the fact remains that both they, and the many pedagogical experiments under way, are usually the outcome of a current of radical criticism of the present system.

Another dislocating factor is the entry in force of the multinational electronic companies into the education technology market. It is possible moreover that owing to their broader, less compartmented internal information space than for traditional education institutions, these companies will succeed in devising a better integrated educational "package".

But these are not the essential considerations. It is not these centrifugal or exogenous forces which are threatening to disintegrate the system so much as its own endogenous forces, and the combinations coming into being within the sub-system of interaction between "education-science-technology-employment".

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(71) "An audio-visual emission of 20 minutes contains 10 to 20 times less distinct information than the columns of a newspaper read for 20 minutes" L. Geminard, ref. 31.

(72) J.S. Brunner - The process of education - New York 1963.

Education is breaking up at the top. But it is breaking up slowly, with no spectacular signs. It is doing so as a result of the disintegration of knowledge, and because knowledge models have failed to produce new combinations of knowledge.

The movement towards ever greater specialisation in education is powered by a combination of forces: the production of fragmented scientific and technological knowledge, solidifying and fragmentation of scientific and education institutions, the interests of the practicioners themselves and the desire to individualise education.

The tendencies for the education system to break up at its higher levels, meanwhile, do not make it any easier to formulate knowledge models in which new knowledge can be integrated.

The actual breadth of these processes, and their consequences, are doubtless masked by the very fact that higher education in its various forms is never subject to appraisal and remains practically shut out from the field of investigation of pedagogical research.

In the last analysis, it is all a matter of the problems confronting the education system.

The definition of the objectives system is logically prior to that of the pedagogical model. The pedagogical model, to be constructed iteratively, would appear to require a pedagogical theory demanding substantial progress in pedagogical research. This can be obtained neither through "incrementalism" nor through "arrogant globalism" (73), but through the formulation of problems in such a way that they reflect the real total systems more and more closely, deriving from a succession of models. Pedagogical research implies not only the "horizontal" integration of disciplines but a "vertical" integration throughout the school age, one which should make provision, in particular, for the evaluation of higher education.

Fragmentation in scientific and technological knowledge has the effect of functionally disintegrating higher education. Such disintegration does not permit a synthetic reconstitution of the knowledge model.

As a result, the knowledge model no longer really governs the pedagogical model, which thus becomes more an ideological plaything, and one which is more or less hazy, than a finalised concept. This also prevents the formation of new combinations of knowledge in programmes and curricula.

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(73) As put by M. Crozier, op.cit. reference 63.

Such fresh combinations would probably encounter resistance from those trained under a different disposition of knowledge and institutions, set up in response to the division of knowledge, labour, and inter-institutional power relations.

If this diagnosis is accurate, the problem is to identify the "modes of interdependence" in the system of systems in interaction, on which to concentrate action, and to identify the corresponding action variables.

D THE "SCIENCE-TECHNOLOGY" SET

1. Science - Technology - Technique

The "education-employment-science and technology" model (74), as explained (75) considered science and technology as a set, including "production systems" which lie at the intersection of the economic and technological sets.

The greater set under consideration therefore comprises:

- reference classes in the scientific set: scientific and technical research facilities and institutions; scientific methodology.
- in the technology set: technological research and development; technology transfers; production systems.

The scientific and technological system (STS) receives as inputs: the "products" of the education system: scientists, technicians, auxiliaries and manpower, and material inputs.

It produces as outputs: scientific and technological knowledge, innovations and technical objects.

It interiorises a proportion of its outputs, scientific instruments, calculating devices, documentation.

Scientific and technological knowledge "operate" upon the education system at the level of programmes and curricula. They are transformed, in the education system, into knowledge models. In the advanced industrial societies these form the substratum of the cultural model.

The STS also directly operates upon the cultural model through technical objects, mediators between nature and man, which create and modify the individual's environment.

It clearly stands in a causal relationship with production systems. But it is also drawn, by the influence of the cultural model, through technical objects.

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(74) See page 10 and legend II to 17.

(75) See A - Epistemological notes, page 16.

Technology transfer is conditioned by the technological knowledge appropriation mode, and occurs within a network of social relationships.

This model clearly implies an STS emancipated from higher education and functionally developed.

A common feature of contemporary development is the loss of a clear-cut distinction between science and technology. "We can see a clear distinction between pure science at one extreme and the development of "hardware" at the other, but there is a large grey area in between" (76)

In physics, for example, the study of high energy elementary particles is at one extreme of pure science, yet it uses the most sophisticated modern technology for its instruments.

Electronics is a real "technical science", in which the distinction is abolished, at least at the design stage. (28)

The previous distinction between "experimental" and "technical" sciences no longer means much in many activities.

One of the reasons for this continual rapprochement between science and technology is doubtless the growing extent to which they are dominated by mathematics.

The relationship of mathematics to the natural sciences is one of constitution, not application. Mathematics is the very existence of theoretical physics, and more than a mere tool in experimental physics (77).

Technique has different meanings: the way in which something is made, the art, skill, application of theoretical knowledge to production; these meanings are loaded with an historical development and continue to co-exist in ordinary language.

We know that historically, it is wrong to imagine that technological development follows on from scientific progress. Scientific knowledge has not governed technological development from era to era.

Scientific progress and research have often been initiated by technique. (78) (79)

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(76) Harvey Brooks - Can science be redirected? O. cit. ref. 17.

(77) Louis Althuser - Philosophie et philosophie spontanée des savants - document cited reference 19.

(78) Maurice Daumas - Histoire générale des techniques - Vol.1 PUF 1962.

(79) M. Daumas gives the following examples: the first internal combustion engines worked without the aid of thermodynamics. The first aircraft flew without that of aerodynamics. The science of radio-electricity was born after the first wireless telegraphy transmissions, and electro-acoustics after sound recording. The first plastics owed nothing to the theories of chemical synthesis.

The junction of sciences and technologies began before the first industrial revolution, but has taken a new course over recent decades.

The internal dynamisms of science and technology have by combining developed a higher synergy, of which the contemporary scientific and technological revolution is the product.

Although it is hard to say exactly when it appeared, the term "technology" appears fairly recent (80). Although it is often used indifferently instead of the word "technique" it does not mean exactly the same thing.

The underlying idea is a reciprocal link between science and technique (78). In other words, an interaction sub-system between them.

Technology is a set encompassing techniques, an intersection of concepts and techniques. It is a configuration, and therefore a structured relationship of techniques.

The modes of link, association and union of techniques among themselves, i.e. their intrinsic relations, in a combination which differs from the sum of the parts, are what form technologies. The new technological combination provides the constituant techniques with a specific extrinsic relationship to the whole.

Technology uses and creates techniques (81). Technologies thus have a considerable polymorphism.

Technology is also a sequential process, designating "the whole set of knowledge and methods necessary to the design, manufacture and exploitation of all materials or technical objects (31).

The continuity of science, technology and technique in regard to the production of technical objects and knowledge does however conceal a deep, sometimes unnoticed fissure.

Technology is not transferred in the same way as science in society. The strategic portion is appropriated and alienated by the private company. It will be essential to refine this question, which has serious political and institutional implications. For example, in most of the developing countries, where the "basic research-technology" chain (82) is almost non-existant, the real chains are "economics-technology" and "politics-technology".

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(80) The definitions of technology and technique differ from one author to another and are often hazy.

(81) It "uses" them without "consuming" them. For use does not destroy the existing structure, unlike consumption.

(82) E.A. Heaffner - The innovation process - Technology review March April 1973.

2. Structural elements

Here too, rather than enter into a tedious description of the elements of the system, it will suffice to analyse the principal points.

The structure of the scientific-technological system is more complex and still less explored than that of the education system.

In the education system the transformations to be brought about involve two main protagonists, the emitter and the receiver, the teacher and the taught. The nature of the messages to be transmitted and assimilated is the same. Indeterminacy, by no means uncommon, stems essentially from insufficient understanding of the conditions for change in the intellectual "representations", and in failure to evaluate the results of higher education.

In the science-technology-technique process, the transformation is more complex.

(1) Scientific information, theories and concepts are forged in accordance with a specific scientific methodology. Science aims to acquire new information about reality. It endeavours to formulate explanatory and predictive systems. The scientific step is made up of a continuing iteration between the theoretical moment and the experimental moment. To move from theoretical construction to experimental practice, an intermediary is required - the model. A model is "an abstract construction designed to provide a schematic, idealised approximation to the concrete domain with which one is concerned, whose structure is sufficiently simple to be describable with the conceptual resources at one's disposal".(83) Constructinn of the model is therefore governed by a certain pre-comprehension of the reality under study. The theory, in "its perfected form is a system, i.e. a perfected conceptual configuration all of whose elements are independent, which shows through its very structure its internal coherence and its character of saturation" (83).

The hypothesis "has as its aim both the original propositions of the theory and the associated model" (83).

The experiment is a form of non-natural action. "It is a constructed action which obeys the suggestion of a prior model and allows itself to be guided, at each stage, by the indications of the theory, which makes it possible to study the model behind it" (83). The validation, or not, of the model chosen may lead to a fundamental modification in the underlying hypotheses. This involves re-organisation in one of the sectors of science, destablisation of the structure, the emergence of a new theory and new concepts,

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(83) Jean Ladrière - Les enjeux de la RATIONALITE; Le défi de la Science et de la Technologie aux cultures - AUBIER - UNESCO 1977.

Scientific activity, by creating new information, increases the "variety", i.e. the number of states, of the theoretical system of reference. It thus transforms "an item of information realised objectively in the form of organisation into an item of information realised in the form of conceptual representations" (83).

(2) For technology, the aim is to transform the given reality. It injects information into existing systems. But it acts in the opposite direction to scientific activity. It consists of "transforming information realised in the form of mental representations (plans, operating diagrams, rules of procedure) into information realised in the form of objective organisation, in other words, projecting an abstract, free item of information (consisting precisely of a representation) into a concrete medium which through that very projection receives a supplementary organisation" (83).

This analysis can be summarised by the following transformations:

scientific activity $R_{t-1} \longrightarrow O_o \longrightarrow \Delta_i \longrightarrow R_1$

technological activity $R_1 \longrightarrow I\ \Delta_1 \longrightarrow O_1$

where R_{t-1} = pre-representation; O_o initial state of organisation
Δ_i supplementary information, O_1 : new representation
$I\ \Delta_1$, incorporation of the supplementary information, O_1
new state of the organisation.

The organisation supplement $(O_1 - O_o)$ adds artificial systems to the natural systems.

Technology operates a mediation with nature. Its iterations are sources of problems for science, usually through deduction for the science-technology movement, and induction for the technology-science movement. (28) (84)

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(84) William Shockley - The invention of the transistor - "An example of creative failure methodology in the public need and the role of the inventor" Edited by Florence Essers and Jacob Rabinow - National Bureau of Standards, Washington DC May 1974.

(3) scientific information is transformed into technical inventions in the new dynamic of a process which is more guided than in the past.(85). An invention is the creation of a unique system out of two systems of actuality and virtualities. It often lies at the meeting point of two or more conceptual fields (86).

(4) A proportion of inventions are transformed via research and development into technical innovations (87). These presuppose the merger, into a single concept, of the recognition of the technique and practicable demand (88).

(5).Technical innovations are transferred, without modification between enterprises, sectors of activity, and countries, where they give rise to changes in use, and to new technological developments and innovations. Technological transfers are outputs and inputs of innovations (9).

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(85) We have seen that this has not always been the case and the technical invention can precede, and be largely independent of, scientific knowledge

(86) Phenomenon of "bisociation" - see KAUFFMAN - Introduction à la combinatonique en vue des applications. Ed. DUNOD

(87) "Invention is a new device, mechanism or process conceived by the human mind, innovation is the introduction or application of a new idea or invention". R. V. Ayres, Prévision technologique et planification à long terme. Ed. Hommes et Techniques 1972

(88) William Gruber and Donald D. Marquis - Factors in the transfer of technology. MIT Press 1969

They, too, involve emitters and receivers, but also an "organisational network" of other agents, (89) (90) whose density will be greater or lesser according to sector and development level. They occur in a network of social relations, i.e. powers.

(6) This leads to consideration of technology in terms of its two sides, exchange value and use value.

(a) As use value, technology shows itself in reference classes whose existence is not apparent: production systems (91).

(1) Production systems (for example, small-scale or one-off production, mass production, continuous production) condition the "profiles" of technology transfers: order relations among the transfer channels, their relative importance, the duration of the operations. Production systems and technology transfers thus have a causal relationship. The production system is a set encompassing the technology mix and the characteristics of the product. The use value of technologies is revealed by two sub-sets of production systems which constitute interactive sub-systems: the sub-set of technological modules, and the sub-set of technical objects.

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(89) William E. Evan - The organizational set - Toward a theory of inter-organizational relations - in James T. Thompson "Approaches to organizational design" University of Pittsburg Press 1966

(90) Robert Emile Miller - Université du Québec and MIT - Entreprise et innovation - Etude comparative de onze entreprises sidérurgiques européennes et américaines - Presses Universitaires Grenoble 1975.

(91) Mrs. Joan Woodward - Industrial organizations: theory and practice - Oxford University Press 1965

Mrs. Joan Woodward has defined IT production systems in three major classes. These systems appear to govern the type of management and the hierarchisation of employment in firms.

(ii) The technological modules in this representation are the elements of the technological system considered as the elementary unit of analysis (92).

By analogy with the phenomena of linguistics, these can be basic technological modules called "technemes" (93). They are information loads arranged into a pattern, and constitute the first incorporation in concrete terms of abstract scientific information and representations. They often form with these a diffuse zone belonging to the two sets, in which the distinction between science and technology no longer has much meaning. Technological modules may associate with one another indefinitely in more or less complex combinations and give rise to the production of millions of objects.

(iii) The world of "technical objects" has hardly been explored (94). It reveals a hierarchical structure. The stages are the elements (e.g. triodes, klystrons, magnetrons), individuals (radar, television, electronic calculator, turbine, alternator etc.) and collections or sets of technical individuals (workshop or laboratory).

These stages may be supplemented by those of technical sets (industrial complexes) and sets of systems (95).

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(92) As an approximate idea, they correspond to the 30,000 or 40,000 terms in the Thesaurus of engineerning and scientific terms" Joint Engineering Council, New York 1969.

(93) J. Baudrillard - Le système des objets - Denoël - Gauthier 1968.

(94) Gilbert Simondon - Du mode d'existence des objets techniques. AUBIER-MONTAIGNE - 1969.

(95) The growing complexity of the techniques to be mastered has led to dissociation of the functions of design and realisation from those of production and the appearance of a new profession: engineering (see J. Perrin - Engineering: terminology and economic function - OECD Development Centre February 1976).

The transfer of technical content occurs most of all at the level of the elements. Technological exchange mainly involves the level of individuals and technical sets.
The synthetic act of invention creates a new "technical essence" which is a new structural combinations. This is the point of departure for a "technical line". The line comprises the intrinsic possibilities for evolution, improvement and differentiation.
There is a mass of technical objects byt "technical lines" are relatively few in number (96). This analysis will be taken further later on.

(b) As exchange value technology is transferred in a network of powers. Behind the apparent, but real, forms of the transfer, commercial and contractual, channels, are hidden the deep and abstract forms of technology: "alienated", "capitalised", "socialised" and "intellectualised" (9)
It is by understanding these forms that the nature of the intrinsic and extrinsic relations in the exchange can be apprehended.
(7) Successive transformations of scientific information into technological inventions and then innovations imply selection from stocks.

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(96) Thus in chemistry, the three million existing products apparently stem from 500 basic technological processes. The latter appear to correspond, for this industry, to the category of "technical lines" identified by G. Simondon.

Only a small proportion of scientific information is transformed into technical inventions, despite the closing of the gap between science and technology. Only a proportion of inventions give rise to innovations, after lapses of time which are admittedly tending to shorten. This applies to instances of "deductive" sequences (28) going from the scientific and technical possibilities to economic applications (push approach).

But there are cases of "inductive" sequences (28) which proceed from problems perceived to their technical solution (pull approach). The second appear more numerous, but the first are instances of major innovations (97).

The filtering and selection of ideas for possible application in the case of the deductive sequences are guided by the world of existing objects, or at least, of those constituting the reference. In the second case, induction by the socio-economic system is direct.

It may even be felt that social-cultural induction exerts a pressure on technical creativity.(98). This induction is revealed in the selective initiation to the discovery, by pre-censorship at the level of the firm, in terms of "acceptable" novelties having regard to existing social values and a general state of force relations between categories of objects. A second censorship level operates by project selection, and in the form of the "modelling" of the object. Thus, various "conformity pressures" are exerted throughout the technological creation process. The dominant forces in the socio-cultural system, the cultural model, of which technical objects are an essential part, exercise more than a feed-back upon technological creation. They have a teleological relationship.

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(97) H. Brooks (ref. 76) gives the examples of the maser and the laser. In medicine, too, the market does not appear to direct the process of innovation (see James J. Dickson - Bringing technology into biomedicine - in "Selected essays on innovation", Auegbach publishers 1971

(98) H. Bianchi - Création, technique et contrôle social - Association française de science économique - Colloque Progrès techniques - Lille October 1974

The intrinsic logic of the technical objects is, in turn affected by them: owing to the system of the objects, they "all continuously flee from technical structurality towards secondary significations, from the technological system to a cultural system. The extra burden of the inessential in the object compromises its objective status and reduces the structural autonomy of the technological level". (93) (99)

The only technological developments which appear to be free of such socio-cultural induction are those stemming from the needs of science itself. (100) The scientific-technical system is then functioning in a closed circuit. Then the loop opens, and engenders a new technical line.

(8) The STS presents a structure of hierarchised layers (101): items of scientific information; technological modules; technical objects; production systems; technology transfers. The relations of scientific method (observation, experiment, deduction, model, theory) are feedbacks. Science and technological R&D also give rise to feedbacks.

Part of the STS is "administered", particularly where it is involved in major civil and military technological programmes. The extrinsic characteristic of the administered STS is therefore teleological.

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(99) In: "Pour une critique de l'économie politique du signe" Gallimard 1972 - Jean Baudrillard supports the thesis that needs are more or less specified in advance by the objects and that the use-value, too, is not an inherent function of the object but something socially determined. "Fetishism" in the exchange value through trading should therefore be supplemented by "fetishism" in the use value through objects.

(100) H. Brooks - ref. gives the example of scientific and technological developments in the field of superconductivity.

(101) For the concept of layer see the model of M. Mesarovic and Edward Pestel - Strategy for tomorrow - Second report to the Club of Rome (in French, Edition Seuil 1974).

But the majority of intrinsic relations are causal. The order in which the sciences appeared is doubtless not arbitrary. Sciences change structure, give rise to other structures, new disciplines, according to transfers and internal changes: the ideologies of the model hold back or facilitate the emergence of new scientific classes. But the construction of the fundamental science in a discipline obeys no plan or ultimate purpose. (23) Technological modules are usually linked by causal relations to items of scientific information. Their combinations give birth to the technical elements.

These, in turn, are integrated in the technical sets and individuals.

In the technical individual, intrinsic and extrinsic relations are circular. Which confers stability, internal and logica coherence upon it.

But viewed as a set, the conception and realisation of technical objects, despite the exceptional cases mentioned above, are guided teleologically.

The massive integrating force of technology thus appears to be due to a conjunction of teleological relations and circular coherences.

The "autonomy" of the STS seems to draw its origin from its feedbacks and circular relations. The autonomy becomes more and more relative the further one goes up in the hierarchy of layers: under heavy fire at the level of technical objects, it becomes very weak and practically disappears in technology transfers. Briefly, within the STS, the sciences have causal relations among themselves and towards the total system. The mechanisms of scientific creation and of the technological individual arecircular relations or feedbacks.

Technical objects, considered globally, and technology transfers are responses to goals, externally lead.

They are lead on the one hand by the ripple effects of socio-economic systems (profit, for example) and on the other hand, by cultural models.

In the advanced industrial societies, the cultural models are operated on in two ways by the STS: directly, by the penetration in force of technical objects, and indirectly, by the knowledge models which are a transformation of STS information.

There is consequently a circular relation between cultural models and the STS. But this relation is at the same time circular and teleological.

The objectives are in fact oriented, in contemporary capitalist societies, by controls "upstream" of the knowledge-production stream by the appropriation of scientific and technical knowledge, the direction of research (28), and "downstream" by the imperatives of the internationalisation of production (102), the pressures of social conformity, compromises between the scientific and technical constraints, and the economic and social constraints.

The decisive question is therefore how to widen the bases of social control and improve it qualitatively, by developing cultural secularisation.

(9) The outputs of the STS operate directly upon the education system through information, theories, models of scientific and technological knowledge.

Entry is effected at two levels: via pedagogical research, and via curricula and programmes. The latter entry point is of capital importance for the interactions of the education-employment-science-technology systems.

For it is on the basis of these curricula that the teachers, scientists, technicians and manpower for the various activities will be trained, or train themselves. The configuration of the inputs will to a great extent define the configuration of the outputs. Here there is certainly an instance of circular causality.

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(102) Christian Palloux - Les firmes multinationales et le procès d'internationalisation - Maspero 1973.

A "social" redirection of science and technology therefore solidly poses the problem of possible new combinations of knowledge.

The stake is of capital importance. Because new combinations of knowledge, resulting from a revised "pre-model" of knowledge, would start off a new loop which would probably give rise to a new knowledge model which, in turn, would operate upon the cultural model. Then another new loop, starting from that one, would project other orientations for scientific and technical development.

(3) Basic problems

Doubtless at some risk of simplifying unduly, the problems of the STS can be consolidated under three principal themes:

(a) the debate on the image the STS has of itself

(b) technological culture and education

(c) technology transfers.

(a) Debate on the state of the STS

There are apparently two opposing theses. In one, science and technology, making themselves autonomous, generate their own self-constructinn and build themselves up into systems and a super-system.

According to the other thesis, the additional information procured by science and technology only end up, to the contrary, in a multiplicity of narrow, unstructured representations.

The elements of this debate underlie the previous analysis in this paper (see Elements of the structure of the Science-Technology set). The principal terms may be briefly repeated.

(i) Thesis: the scientific-technological order

One of the features of the way science has evolved has been the increasingly tight links between its various constituents. This has meant that science has been integrating itself. General theories have been applied in the most varied fields. Integration has been at work not only within particular scientific disciplines, but within those disciplines taken together.

The development of science "will therefore apparently be less and less dependent on external, contingent, relatively uncontrollable circumstances, and increasingly linked to internal factors (of equilibration, disturbance, re-equilibration, self-organisation)" (103).

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(103) On the discussion between the theses of "internalists" and "externalists" see F. CHESNAIS - Réflexions sur le concept de système scientifique et technique - Annales de l'Association française de Science économique. Seminar 1974.

This suggests the following hypothesis: "In contemporary societies, science (considered as a whole) will have a tendency, under the impact of its own internal functioning, to form itself into a vast system, itself made up of interacting sub-systems, evolving towards increasingly complex and increasingly integrated forms, which are at the same time increasingly autonomous" (83). The same would be true of technology. Technological operations are increasingly interdependent. They tend to integrate themselves within a vast operational network. This network not only has linear links, as in a tree structure. Interdependences may establish themselves among nodes belonging to different levels and form retroactive links. It is "increasingly from the departure point of its internal possibilities, and not from that of external situations or needs, that technological activity will define its objectives, these becoming increasingly independent of motivations which are not strictly technological, from other sectors of culture or simply from the "primary needs" system" (83).

By a sort of inversion, "it is the future of technology itself which governs the system of needs".

In a word, "the technological domain, just like the scientific domain, appears to be evolving towards increasing self-determination of ultimate purposes, to the extent that it organises itself into a relatively independent network of increasingly interdependent partial systems, and that this network appears to be capable by itself of increasing its level of organisation and integration" (83).

Science and technology apparently tend, moreover, to constitute together a unique superstructure. Translated into the terms of the model used in this analysis, this thesis means that science and technology will be moved by teleological relations. But their ultimate purposes will be determined by the logic of their internal causal, order, reciprocity and feedback relations.

(ii) antithesis: science and technology in fragments

The 1970s seem to mark the end of a conquering if not triumphal period for science and technology.

The "scientific and technical revolution" has not been followed by a counter-revolution but by a serious reflux. This has taken the form of a relative decline in the resources allocated to them and most of all, by disenchantment and a weakening of support from public opinion in the advanced market economy industrialised societies.

In 1971, the special OECD group on new concepts in science located the difficulties of science in the context of the "disarray of society" and presented a "new perspective" to meet new social aspirations (76).

But in 1977, the "redirection" of science and technology seems hardly to have been embarked upon (3).

There are some formidable obstacles in its way.

The first, long concealed by the confident mood which scientific and technological successes have brought about, is the rupture of the unity of knowledge.

The process of disintegration for science, which began in the 17th century, has been unceasingly accentuated. (104)

"Unitary science explodes like a shell, whose own fragments continue to move away from one another in their trajectories... the progress of knowledge, very far from corresponding to any organic development, calls to mind the random proliferation of cancer cells, each multiplying on its own account irrespective of any overall regulation, with the risk of intellectual death this implies.... the sociological and demographic disaster of the universities in today's world conceals the epistemological disaster brought about by the galloping inflation of specialisation... a fragmented science is the science of a fragmented spirit. The cancerous condition of knowledge leads to a distorsion of mental space". (104).

Scientific progress has thus been achieved by means of deep thrusts into increasingly narrow areas.

This leads to a paradoxical situation.

Collectively, man knows more about his environment than ever before in history, but individually his knowledge is limited to a mere fragment of the knowledge accumulated (105).

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(104) G. G. interdisciplinaire (connaissance) Encyclopaedia universalis
(105) Leslie Walter Boxer - Self-Knowledge and historical perspective in a science-conscious society - in Leslie Holliday: The integration of technologies - op. cit. 130

The contemporary reaction to a fragmented science is pluridisciplinarity and interdisciplinarity.

Interdisciplinarity, "defined by the technical exigencies of an order, appears as the obverse of the division of labour, its recomposition in a collective work ... the concept of interdisciplinarity indicates not a solution but a contradiction" (106).

Some well-disposed people cast doubt on this concept, as practised by juxtaposition or addition of specialists.

The demands of interdisciplinarity are higher. They imply nothing less than a "re-allocation of mental space" (104) ... "interdisciplinary intelligence will only reach the arrival post of individual or collective research if it is present from the outset" (104).

" ... interdisciplinary understanding can only advance through education of the interdisciplinary sense: it is a question of awakening a new form of understanding" (105)

Since it would not be very realistic to contemplate modifying the scientific work regime in the specialist methodological frame, it is into the minds of the savant and the student that the new intelligibility must be projected.

The disintegration of knowledge is consolidated by the institutions "each new discipline installs itself comfortably, with its own facilities, and in so doing gives an administrative sanction to its separation 'in bed and board' from knowledge as a whole" (104). This in turn, develops another circular causality. "The proliferation of institutions taking over the management of each parcel, ends in the formation of a feudal system governing nearly all scientific, educational and research undertakings. The specialist, having transformed his speciality into a fortress, gives free rein to his desire for power" ..." the compartmental system enables the specialist to divide and rule, avoiding control and confrontation" (104)

These quotations are long, but they are of interest in that they describe, in terms of systematic analysis, the internal coherence of scientific segmentation.

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(106) L. Althuser - op. cit. ref.77.

The fragmentation of technology is even more marked, combining the effects of fragmentation in its scientific bases and the compartmentalisation of tasks in industry (107).

Modern technologies have experienced no setbacks so far as the objectives assigned them are concerned. But their ecological bankruptcy stems from their reductive method, described as a fragmentary analysis, the tendency to believe that one can manage to understand a complex system by looking separately at the properties of each ot its parts. (107).

As regards the compartmentalisation of tasks, stemming from economic objectives and the division of labour "this imperative ... determines the shape of technology and almost all its consequences, and the whole pattern of modern industry." (108)

Here, too, a series of causalities comes into operation. Science and the division of labour fragment technology. The fragmentation of technology is reflected in technological education. The specialists produced by the latter emphasise specialisation. Defence of professional standing reinforces this, and influences the direction of curricula and examinations.

The fragmentation of science and techniques are, together with social diversification, at the root of the segmentation of education and the disintegrating tendency in higher education.

(iii) Remarks

This is hardly the place to offer any conclusion to the debate this opens up. But a number of points may usefully be suggested in terms of the above model.

In particular, the hypothesis may be advanced that the thesis and antithesis are ultimately two sides of a huge contradiction.

This can perhaps be described in more detail, and a number of distinctions not available in their general formulation may be introduced.

The systematic unity of science doubtless requires analysis not from the standpoint of "science" but from that of the relations which hold among the sciences themselves.

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(107) Barry Commoner - The closing circle - Knopf New York, 1971

(108) J. Galbraith - The New Indistrial Estate - Houghton Miffin.

The distinction introduced between application-relations and constitution-relations (mathematics for example) (77), represents an advance in understanding here. The extension of the constituent sciences and the proliferation of application inter-relationships among the sciences not only engender interactive sub-systems (new disciplines) but create a denser and denser network. It may therefore be conceded that this network is objectively shaped in accordance with an order not exclusively but mainly dependent upon its dominant internal relationships. But this order is not apparent, and it is only partial. Ordinary scientific information carries a load of metric rather than structural information. Unitary representations weakly integrate juxtaposed fields, and are late in comparison with the real movement of interdependences already in being. The image is that of a kaleidoscope composed of fragments.

This majestic structuring movement occurs under conditions of anarchic proliferation, cancerously, in the various disciplines. The structuring movement attains only a proportion of the reference classes. The intrinsic and extrinsic relations between the remainder, escaping in apparent disorder, are indeterminate. Transfers from one class to another are impossible or infrequent owing to their tendency to isolation, the absence of applications and of relations from field to field. Each class renders the information it produces more dense, but the structural content of such information is low.

The relative autonomy of science in the way it is run, its tendencies to self-organisation at the level at the system, also contain their opposite, tendencies for the organisation to break up at the level of the system components, institutions and scientists.

As regards technology, despite the integrating forces of the technical object, which will be analysed further ahead, it must be recognised that the analogy with the thesis that science increasingly determines its own ultimate purposes is an analogy requiring qualification. Despite the power and logical consistency of the internalising forces of technology, they are more open than those of science to the attraction of the external force field, both as to instances of invention, innovation, and dissemination. This is precisely due to the fact that abstract scientific information has its concrete embodiment in technologies, and in an organisation which is inter-related with the social organisation as a whole.

At all events, it may be conceded that the variety, both of the technological system and of the scientific system, are growing apace and represent a vast mass of information. If the scientific and technological systems are setting their own ultimate purposes at least to some extent, and to a greater extent in the case of science, this goes some way to explaining the difficulties of social control over science and technology. According to the well-known law of required variety (109) "a set of variety V can only be wholly controlled by another system of the variety if the latter is at least equal". The action systems inside and outside the systems, communities of scientists and technologists, higher education, teachers and society in general can only control science and technology by increasing their own variety. "Only the variety of an action system enables it to reduce the variety of its environment ... only variety can reduce variety" (110). The understanding of systems and their structures is one of the sources of variety.

Understanding of the science system is doubtless less remote than that of the technology system. This leads back to the general point made at the beginning of this study about the impossibility of arriving at an understanding of the total structure of the theoretical system (111) of education, technology and science. For the latter, of the eight groups of data defining the system, many are known (112): the existence of reference classes, how many of these there are, if not of the elements in each reference class, and the existence of relations among reference classes. But the task remains of systematically investigating the intrinsic and extrinsic characteristics of each reference class (for example, the setting of its own ultimate purposes as an extrinsic characteristic), the type of relation between reference classes (i.e. the architecture of the assembly of intrinsic and extrinsic characteristics). For the technology system, the data available are currently hazier and most of the relations remain to be explored.

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(109) W.R. Ashby - Introduction to cybernetics - Dunod 1958 Design for a brain - Chapman and Hall 1960.

(110) CH. Roig - Analyse de systèmes en Sciences Sociales - perspectives de développement théorique. Association de science politique Paris, April 1970.

(111) See pages 19 and 21,

(112) The Unesco classification of scientific and technical terms (the

(b) Technological culture and education

The absence of social control over science and technology, the destabilisation of cultural models brought about by science and technology in many developed market-economy countries and developing countries, naturally lead to criticism of rational positivism and in some cases, to calls for a return to spirituality, to the wisdom of non-western civilisations, a revaluation of Utopia.

These proposals will not be discussed here, but one decisive point may be emphasised.

Mastery over science and technology can only come from the "centre" at which they are produced, and from which they are disseminated.

The "peripheral" countries, as has been stressed, will require heavy transfers of technology to implement their industrialisation programmes, what ever effort they put into producing their own.

It is therefore more likely that "modernisation" (113), with the accompanying transplanting of advanced society roles into developing countries, will occur and become more accentuated, than the opposite.

The "non-aggressive", "soft" "intermediate" technologies stem from a new cultural model (114). But their elaboration, adoption and implementation depend upon a social foundation which is usually lacking in a developing country, with the notable exception of farming communities (9).

While contributions from other cultures and civilisations may be valuable correctives to the development model of the industrialised countries, so far as science and technology are there is no escape route for the "centre". It is up to the "centre" to master the processes it has set in train.

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(113) David Apter - The politics of modernization - Chicago - University of Chicago Press 1965

(114) This is supported by the trend in the thought of the promotors of intermediate technologies. In "Small is beautiful - Economics as if people mattered - Perennial Library 1975, E. F. Schumacher logically places the policy of intermediate technologies in a different cultural model.

Their powerful cohesive forces, not subject to social control, will not cease to function merely by virtue of philosophical or ideological incantations, however justified.

They can only be dominated if the "heavy power" of education (23) is brought to bear for the purpose.

Response to the challenge for civilisation from a scientific and technical revolution not dominated by the socio-economic system lies not in a de-emphasis of education and research but on the contrary, in the development of technical education and the dissemination of a technical culture.

(1) The integration of technologies

As we have seen, technology is the seat of a curious contradiction. On one side the increasingly specialised human intellect, education, professions, and institutions are segmenting technology into isolated fragments; meanwhile, human activity reintegrates these into individuals, sets and major technological programmes of ever increasing complexity.

This contradiction takes other forms: in the observation, on the one hand, that technological knowledge is a thing of tiny parts, while on the other hand, technology constitutes a powerful integrating force. If both observations are conceded to be just as valid, how can technology be at the same time disintegrated and integrating?

To illuminate this process, we must look once again at the nature of technical objects (115).

The technical object tends towards internal coherence.

The primitive technical object (116) is "the translation into matter of a set of distinct scientific notions and principles, distinct from one another in depth... such an object is the physical delivery of an intellectual system." Of an exploding intellectual system, it might be added.

The evolved technical object (117) is not just a simple application or bundle of applications of these scientific principles. It "tends to close the cause and effect system circling within its enclosure, and it incorporates, furthermore, a part of the natural world which intervenes as a condition of operation".

In other words, the evolved technical object, in acquiring the structure of a system, becomes increasingly comparable to the natural object, it is in this sense that it "becomes concrete".

Its structure has the same status as a natural structure, although it may be schematically different from a natural structure.

Whereas in the primitive object each structure is responsible for fulfilling a defined function, and usually one function only, in the evolved technical object the organisation of sub-sets is functional within the total functioning. "Specialisation does not come about by function but synergy by synergy; it is the group of functions, not the single function, which constitutes the real sub-set in the technical object".

The evolved technical object contains plurifunctional correspondance within a single structure.

These theses may be interpreted in another form.

At the level of the technical object: individual elements (or components), and sets, an internal structure of functions intrinsic to them may be observed. But the elements come together as individuals, the individuals as sets.

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(115) And the basic analysis of G. Simondon - ref. 94

(116) "abstract" in G. Simondon's terminology

(117) "concrete" in G. Simondon's terminology

The technical individual, in which elements are integrated, possesses an extrinsic function; the set, in which individuals are integrated, also has an extrinsic function which is that of the system constituted. Components and individuals can only come together at a higher level to the extent that their intrinsic functions are, in the first place, complementary, and secondly, interdependent with respect to the whole constituted by the extrinsic function of the higher level.

The same applies to technological modules, "technemes", with respect to technical elements.

The extrinsic function of the system is the mode of assembly of the constituents. The intrinsic and extrinsic functions are exchanges of energy and information.

There is a structure at each level, and a structure of the structures at the next level up which encompasses it.

The technical object is an integrator.

"The technical object, far from being wholly situated in the context of any particular science, is in fact at the point of convergence of a multitude of scientific data and effects from the most varied range of fields, integrating the most apparently incongruous sorts of knowledge, which may not be co-ordinated intellectually though they are co-ordinated in practice in the functioning of the technical object".

There is no machine which is not at the same time a thing of mechanics, chemistry and information processing.

"The machine is externally made to obtain a certain result; but the more the technical object individualises itself, the more its external purpose is effaced in favour of internal functioning coherence; functioning becomes a goal with respect to itself, before it becomes one with respect to the outside world".

Several consequences stem from this:

- in the first place, the impressive internal coherence of technology, its "autonomisation" and its potential for reconstituting knowledge which has been broken up into tiny particles;

- then the need, if the system is to be mastered, to"operate"it from inside too, a point in common with the education system;
- lastly, the objective difficulty of modifying technological development to respond to ecological needs and the need to recover non-renewable resources.

The structured technical object, internally self-regulating, is not longer made up of separate and therefore more easily recoverable elements. Recycling must therefore be provided for at the design stage, which implies a broadening of the field of action for the design engineer" (118), and elevating technological R&D to a higher level, rendering the internal logic and unity of the technical object compatible with the subsequent redistribution of its components.

Another point must be made,about the insertion of technical objects into their environment. Technical objects, depending upon their level, either do or do not possess an associated environment.

Technical elements can be distinguished from genuine individuals in that they possess no associated environment.

In contrast, "there is a technical individual when the associated environment exists as a sine qua non for it to function". In the contrary case there is a set.

"There is recurrence of causality between the associated environment and the structures, but it is not symmetrical. The environment plays an information role, it is the seat of the self-regulations... but whereas the environment is homeostatic, the structures are are animated by a non recurrent structure, each going its own way" (94).

Differentiation in the elements of the structure of the technical object permits its integration within the functioning of the whole.

The beginning of a line of technical objects constitutes a "technical essence".

"The technical essence is recognizable from the fact that it remains stable through the evolving line, and not only stable but still productive of structures and functions by internal development and gradual saturation."

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(118) Vincent Labeyrie - La crise de l'environnement, l'économie de la nature et l'économie humaine - Mondes en développement - Crise du capitalism ou ordre international nouveau No.11 - 1975. The research carried out by the M.I.T. should also be pointed out: Robert L. Lund and W. Michael Denney : Extending product life: time to remanufacture? - Center for Policy Alternatives, Massachusetts Institute of technology - 1978 -

The immense population of technical objects therefore contains "families" whose identity it would be valuable to understand for the teaching, and the mastery, of technology.

"Technical species are much less numerous than the uses to which technical objects are put". Technical species have a finite number of directions from which to converge, technical objects evolve towards a small number of specific types.

These theses are certainly not easy, but they fulfil the essential functions of philosophy: to trace the line of demarcation between the scientific and the ideological. (77)

The categories identified are not scientific concepts, but they are not ideological ideas. (119) They provide a point of departure for verifiable hypotheses.

The "technical line" category gives scope for scientific verification. Its point of departure is, moreover, a series of observations drawn from the history of techniques.

It ought to be possible to describe the functions, structures and systems of technical objects with much greater rigour. The difficulty here is the choice of a common language.

The need for a typology of technologies has long been perceived, and attention has been drawn to it by all who have come up against the intellectual and practical obstacle constituted by its absence (120).

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(119) G. Simondon's ultimate conclusions from these theses, not presented here, apparently depend upon his own conception of the world, which L. Althuser defines as the value of the practical ideologies, which do not maintain the same relations as philosophy with science.

(120) In 1867, K. Marx regretted the absence of any critical history of technology. In 1965, Miss Joan Woodward noted that researchers would need a natural history of industry, something like a botanical "flora". Manoury notes the lack of criteria with which to see what part science has played in any one innovation or series of innovations. In 1972, a team led by R. Saint Paul, analysing methods and applications of technological forecasting, found that there was some confusion about the definitions of technology, which led to confusion in the methodology.

A typology of technologies could comprise different stages.

First, that of the laws of association for technological modules.

The study of technical objects at "element" level (121) would constitute the "general organology".

The "mechanology" would study complete technical individuals since technologies go back from these towards the separate sciences, their correlations and transformations would be studied.

This suggestion is practicable.

Comparable methods have been used in military research. The problem was posed like this: missions being defined should lead to the production of new weapons; a "technology-missions" matrix would make it possible to identify the available technologies; the technologies to be created, or perfected, would then provide the basis for the formulation of a "science-technology" matrix. (122) (123). Starting from missions, regression analysis would go back to the necessary, available and foreseeable scientific knowledge.

The road to concrete form lies through abstraction.

The development of chemical engineering offers a good example of the value of abstraction in reducing apparently unrelated activities into a body of ordered knowledge.

(120 Continued) Leslie Holliday feels that we need to do for the evolution of technology what Mendel and Darwin did for the growth chemistry and biology. (The integration of technologies - Hutchinson, London 1966). Hasan Ozbektan has suggested establishing a "periodic table for technologies" (Noted by Erich Jantsh - Design for evolution - International Library of Systems Theory and Philosophy) G. Braziller - New York 1975.
The beginnings of very simple technologies are discussed in the works of G. R. Hall and R. E. Johnson - Transfers of US aerospace technology to Japan - NBER 1979; and James D. Thompson - Organization in action - MacGraw Hill Book Co. 1967.

(121) According tb=G. Simondon's terminology

(122) Marvin J. Cetron - Quest - Status Report -IIEE Transactions on Engineering Management No. 1, March 1967.

(123) Joseph P. Martino - A classification system for military functions, technologies and sciences - IIEE No. 1, March 1967

This is what took place at the beginning of the present century and can be credited to George E. Davis in Britain and Arthur D. Little in the United States, who realised that the operations in chemical manufacturing could be reduced to a limited number of unitary processes and operations, such as the transfer of heat and mass, filtration, distillation (124).

This would mean restoring conceptual order to the vast technological development which has since occurred. Nobody would claim that the task is an easy one, but it would be feasible. The question is one of awareness and political will (125).

"The integration of technologies" which is occurring within the internal technological of technical objects needs to be put back explicitly to the level of the technologists' activities and education. This is the pre-requisite for subordinating the internal logic to external ultimate purposes.

This will require the forging of new methodological tools. No form of planning is exempt from this need. (126).

One of these tools is the development of a descriptive method.

Preliminary attempts have already been made to find a common language for technologies (127).

Recent progress in mathematics (128) may afford new tools, as may the methods of linguistics. (129)

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(124) Simon WOOLF - Abstraction of technologies, in Leslie Holliday, The integration of technologies

(125) This task could moreover be conceived as an extention of the Unesco work on compiling the "Spines" thesaurus. The existence of this major working tool with its 10,500 scientific and technical terms and 74,000 cross references shows that such tasks are not impossible.

(126) This has been true of educational planning, which has had to work out its own methodological instruments See P. H. Coombs, ref. 1

(127) Edward Manougian - Towards a common alonguage for the technologies in Leslie Holliday's The integration of technology. The author shows that the symbolisation of chemical equations can be transformed into the formalisation of set theory in modern mathematics.

(128) The work of L. E. Zadeh on fuzzy sets theory.

Thus a wide new field of investigation opens up.

To uncover the order of technological construction requires that a matching relationship, today disrupted by scientific fragmentation and professional specialisation, be restored with the teaching of technologies. We need to rediscover the disciplines which constitute real "nodes of interdependence" for the technological system, technical lines and objects.

To try to organise the field of technology within broad disciplines represents a fascinating intellectual challenge (130). This could clearly be a stimulus to technical progress, and the transfer of processes among products and sectors (131).

Without waiting for technology typologies, a general mechanology and organology to be produced, it is possible to rearrange technical education curricula on the basis of what we already know.

"New combinations of knowledge" (31) should make it possible to provide "at the outset" the right conditions for interdisciplinarity, to control the disintegration of technologies effectively and, through its recurrent effects, attenuate the disintegration of science.

This is the sine qua non if we are to dominate the internal logic of technology, bring its dynamism under our control, and make it serve externally determined goals, and prepare the way for new circular causality loops.

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(129) Pierre F. Gonod - Social control of the external supply of technology - OECD Seminar: Science, technology and development in a changing world, 21-25 April 1975; New challenges in technology transfer - Worldtech May 1974

(130) Leslie Holliday - Interaction of technologies in the integration of technologies, Hutchinson - London 1966

(131) Leslie Holliday shows that systematic examination of different unit forming processes for various materials - metals, plastics, glass, inorganic substances - reveals hitherto unused scope for transfer.

Here too, we are not dealing with empty dreams but tangible possibilites. The two diagrams attached show what regroupments are possible at a high level of aggregation (132) (133). With a less aggregated analysis, we could doubtless pinpoint those kinds of knowledge which play the role of interdisciplinary pivots.

(ii) Technological culture

Curriculum reform in techncial education opens the way to polytechnism and technical culture.

During the "age of enlightenment" the Encyclopédie, a polytechnical work, provided "a new force and a new social dynamic". (94).

Polytechnical education was one of the major ideas of the Marxist thinkers (134). The dissemination of technical culture, the broadening of the very conept and methods of polytechnical education also appear today to be one of the prerequisites for a 21st century encyclopaedism.

Pedagogical specialists have noted: "producer and employee use a machine as a black box, with no need to understand how it is designed or even how it works". Philosophers have noted: "technics becomes an esoteric mystery". (94). To dissipate that mystery, and avoid myth and mystification, technological knowledge needs to be spread around from the youngest ages onward.

"Encyclopaedism could, through technical understanding, take its place in the education of the child without requiring those capacities for abstraction which cannot be fully developed in the young child. In this sense, the acquisition of technological knowledge

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(132) R. A. Coombe - A technical education - in Leslie Holliday.

(133) In this diagram the expression "lattice structure" refers to macorscopic phenomena such as viscosity, heat transfer, electrical conduction, elasticity etc.

(134) M. N. Skatkin - Marxist-Leninist ideas on polytechnical education in the USSR - Unesco 1963

Table I. SIMPLIFIED REPRESENTATION OF THE RELATIONSHIP OF THE TECHNOLOGIES TO THE FIRST DEGREE

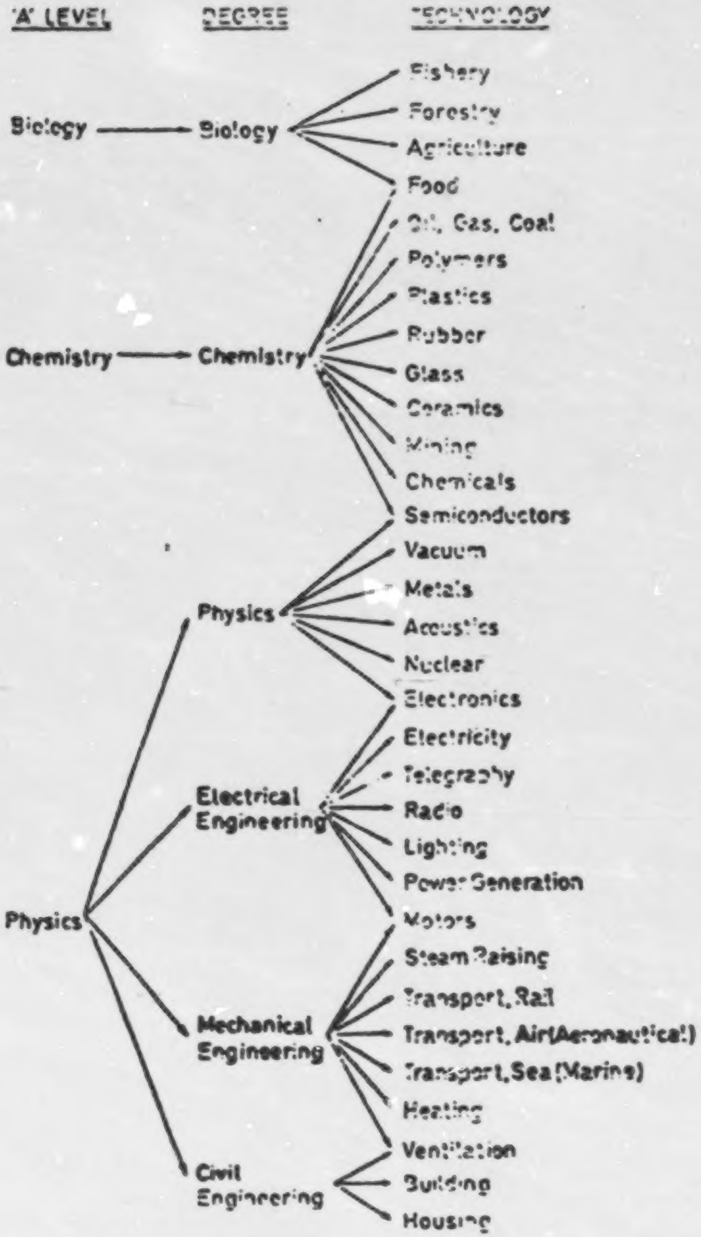
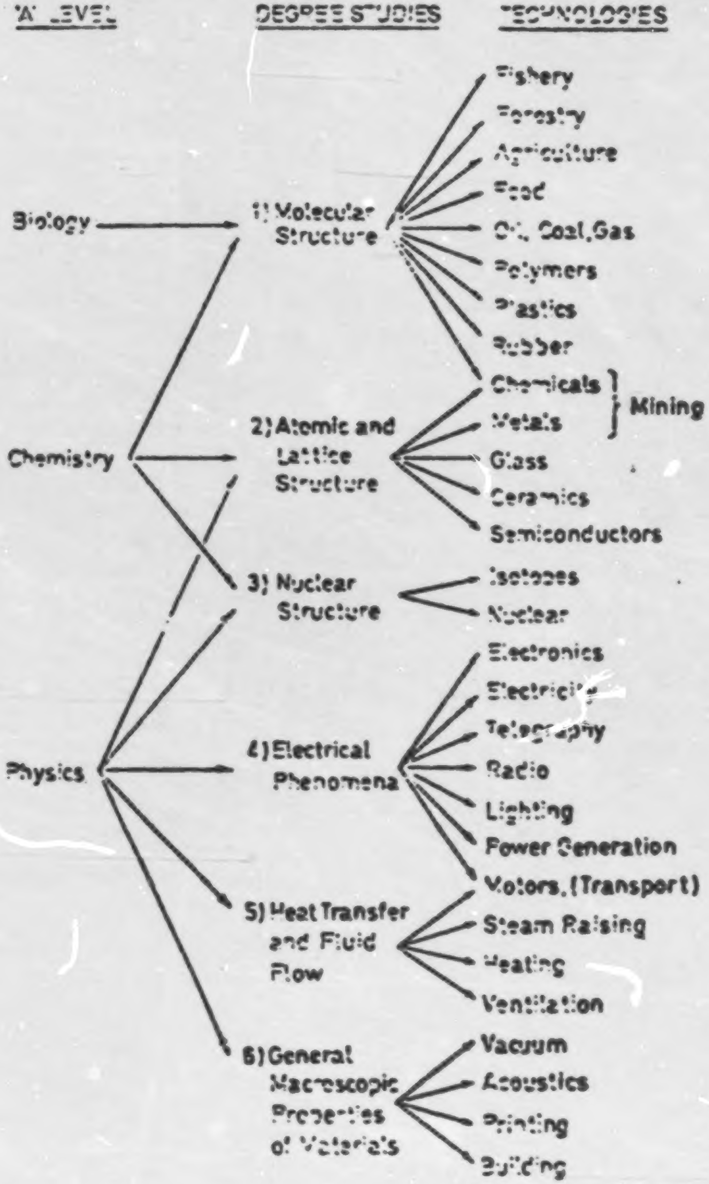


Table 2. DEGREE COURSE BASIC TO ALL TECHNOLOGIES



by the child may initiate an intuitive encyclopaedism, grasped through the character of the technical object" (94).

Technical culture in this sense is not only synonymous with technical knowledge. It comprises the understanding of technical evolution and structure, the generalisation of polytechnical education. The experience of the USSR in this field is therefore of interest.

Insofar as the latter can be properly appraised from published documents, it suggests the following comments:

- it was affected by the general difficulties facing the Soviet régime throughout its history (135);
- it has probably contributed greatly to the development of a capacity for assimilation which has made possible the transfer of technologies with a recognized degree of success. (136).
- but it appears to be localised at the level of the secondary school (137) and to serve as a basis for the subsequent training of specialists, either occupationally or in higher education.

The preceding suggestions would enlarge this base in two directions - towards the younger child, and in particular, towards higher technical education.

"New combinations of knowledge" would bring polytechnicism to its decisive level: the level at which that knowledge is produced which will be the point of departure for technological creation and dissemination, the level at which to penetrate and "operate" upon the circular causality between technical and education systems.

(c) Technology transfers

Technology transfers bring us essentially to the "exchange value" side of technology.

Although modern technology may be science-rendered operational and put into material form, it is not reducible to that universal, oecumenical science of which it is the fruit. Science only becomes technique through exchange and, consequently, social appropriation. This means that it is transferred within a power network. (9).

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(135) I. M. Skatkin - Soviet experience in polytechnical education before the reform (1917-1958) in S. G. Shapovalénko

(136) See Joseph Berliner - The innovation decision in Soviet industry, MIT Press, Cambridge 1976.

(137) S. G. Shapovalenko - The new curricula and syllabuses as the basis for polytechnical education, op. cit. ref. 134

The transfer of technology between market economy enterprises, and between nations, is not a pure exchange, but a "composite exchange" (138).

The fundamental concept of composite exchange is the extrinsic relation of the technological sub-system.

The circulation of technology is, for the most part, not "free" and differs from that of scientific information.

Purely co-operative exchange and pure conflict constitute two unattainable limiting positions.

As its intrinsic relations, the technology transfer sub-system has the constraints represented by the very properties of the use value of technology and the action variables, represented by the interplay of the protagonists involved in the exchange.

The intrinsic properties of technology are those of the "reference classes", technological modules and technical objects contained within the sub-set of production systems.

The study of technology transfers within multinational firms, where the power and struggle/co-operation relationships characteristic of composite exchange are minimised, shows that it is the production systems which determine the shape of technology transfer mechanisms. (139).

The relational structure of technology transfers can then be described as involving two sets, linked by an interactive sub-system (140).

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(138) See Chapter I, The problem posed, page 1, and notes 5 and 6

(139) J. W. Behrmann - H. W. Wallender - Transfers of manufacturing technology within multinational enterprises - Ballinger Publishing Co. Cambridge, Mass. 1976

(140) This chapter summarises part of the analysis in "Nouvelles representations du transfert technologique" to be published, ref. 27

The first sub-set is "Activities", the second, "Agents".

The interactive sub-system is constituted by "Types of transfer" and "Channels".

The activities in technology transfer are many. In the case of an industrial project there are some forty, from exploratory studies, feasibility studies, draft projects, the establishment of projects and detailed projects, the organisation of the structures of the enterprise, recruitment, personnel training, supplies, implementation of the project, activities after the marketing of the output.

These transfer types are "mimetic", "adaptive" or "innovative".

Channels, of which there are some twenty in all, carry technological content.

Technological flows are regulated by industrial arrangements which constitute something like valves for the channels.

Transfer agents always comprise at least an emitter and a receiver (the associated firm or main contractor). But technology transfers are usually indirect and involve more than two agents.

The other agents are: the proprietors of processes, banks, engineering, which may exercise the function of prime contractor in co-ordinating activities as a whole, the designer, sub-contracting firms, brokers, technological information centres, international technical assistance institutes, universities, occupational training centres, technological research institutes.

These agents participate to varying extents in technology transfers.

The combinations established depend on the nature and type of technology transfer envisaged, the respective strengths of the principal emitter and receiver, the critical comparison of the projects of receiver and emitter, their merger into a single project and the industrial arrangement to which this negotiation ultimately leads.

To grasp the mechanisms of technology transfer, two essential processes must be understood: the social forms of technology in composite exchange, and the action spaces of the transfer agents.

To detect the *social forms of technology*, one needs to look beyond the apparent contractual forms of transfer, though those also have their reality, and see the deep underlying forms, which are hidden and abstract.

In descriptions of the forms of technology it is usually embodied technology, i.e. physical goods, rather than disembodied technology which is considered.

The distinction between "embodied" and "disembodied" is not as obvious as it seems.

Technology is always incorporated in something: information has a material medium, understanding and knowhow, man are not disembodied.

Technology is ultimately work, living or past, contemporary or crystallised, abstract work embodied. But the classifications usually fail to take account of the essential point, thattechnology, as a social activity, is an *appropriated* activity, at least in the capitalist mode of production. It is the way in which this appropriation comes about that must be considered. This leads to distinctions between:

Socialised technology: this **means** technology which is socially available and unrestrictedly accessible. It covers free information, knowledge of technical processes which have fallen into the public domain.

Intellectualised technology, which refers to basic knowledge, practical experience, knowhow, assimilated and incorporated by men.

Alienated technology refers to technology which is "retained" and ceded by virtue of a property right or a special agreement.

This covers information which is not free, secret knowhow, part of the techniques of management, technical assistance which is restrictive and remitted by **are** owners of technological processes.

Capitalised technology refers to technology "crystallised" in capital goods, intermediate goods, products, simple or complex production facilities.

It can be acquired in trade.

Capitalised technology is not usually sufficient by itself. It needs to be associated with recourse, in variable proportions, to alienated technology. Technology crystallised in the means of production, complex past work, usually can only be deployed in conjunction with the living work of know-how, i.e. instructions for the use of the means of production. Know-how is a present work which transmits past learning to a workforce capable of assimilating it. This applies to intellectualised know-how.

Written know-how is usually a secret held by the possessors of technology. It has therefore been alienated. Intellectualised know-how can be socialised through technical assistance programmes in which nothing is held back.

Information which is not free and the corresponding know-how, may be socialised through the very obsolescence of the information, or the spread of access to the knowledge by other units. Information can deteriorate with time.

Following this regression from the apparent forms to the abstract forms, the process must be reversed, and we proceed from the new concepts to an analysis of the channels and forms of technology transfer in composite exchange.

The various technology transfer channels can be reclassified as follows:

Socialised technology: technical literature (manuals, articles, drawings, patent documentation etc.; conferences and seminars; basic training through education.

Intellectualised technology: training on-the-job; occupational mobility, direct contact, visits, exchanges, fairs, exhibitions, technical assistance missions.

Alienated technology: "secret" or "retained" information and know-how concerning process technologies (especially "hot core" processes"); product design data; project engineering; marketing organisation; production; R&D.

These social forms may be regarded as something like "layers" in tiers. The capitalist layer constitutes the plinth, the substratum where the "capitalised "channels are the great collectors of irrigation. The "alienated" channels are a deep layer whose absence usually renders the other channels inadequate.

According to how they are integrated socially, the receivers will thus receive a greater or lesser amount of 'irrigation'.

The subsidiary of a large international firm thus appears to benefit from a maximum of contributions, but their content does not tend to develop an autonomous capacity for management and innovation.

With "Active units" as axiomatic, (141), we can advance in our understanding of the structure of technological exchanges.

A Unit is said to be active if "through its own action, and in its own interests, it is capable of modifying its environment, i.e. the behaviour of the units in which it adapts its environment to its programme rather than vice-versa".

An active unit has action spaces at its disposal made up of the decision space, the operation space and the maximum operation space (141).

The decision space comprises the following elements: financial capacity, management (or leadership) capacity, technological assimilation capacity, innovatory capacity, means of production capacity.

The technological emission and reception surfaces form part of the decision spaces. They have all the preceding elements in common apart from financial capacity.

It is within the power of the decision-making centre to alter these elements. These layers are hierarchised and interactive (43).

The operation space is constituted of a clientele environment, an investment environment, and an information environment (141). Through its decision space the active unit acts upon the operation space according to applications of its elements.

The environments of the operation space are interactive.

The maximum operation space can be specified by reference to a period $(t_o - t_n)$ (141).

It results from the action exercised by the unit upon its environment, and vice versa.

It is a resultant of, on the one hand, the limits to that particular unit's decision space, and on the other hand, the boundaries of the environment.

(141) François Perroux - Unités actives et mathématiques nouvelles - révision de la théorie de l'équilibre économique général. Dunod 1975

These boundaries may be at a specified time: the availabilities of the stock of scientific and technological knowledge; the availabilities of social access to technology, the industrial policy environment, that of the market structure, the scientific and technical infrastructure (43).

These elements are constraints. Their impact upon the operation space is as opposing forces to those of the elements in the decision space.

Such constraints are not always present, each maximum operation space is specific. These constraints evolve over time, emerging and disappearing.

Elements in the emitter's and receiver's action space will couple with one another, and in the case of indirect technology transfer, with elements of other agents involved in such transfers.

In such circumstances, the action spaces of the active units are the space encompassing technology transfer activities.

Every instance of technology transfer always reflects an asymmetry, total or partial. Far from being a "gift economy" it implies some kind of counterpart. The counterpart may be financial, industrial, commercial or in the form of cross-licensing.

Technological transfers imply the participation of units whose forces a in overall equilibrium or disequilibrium

Equilibration is effected by means of counterparts,,which are all the more extensive the more pronounced the disequilibrium.

The first equilibration is performed by the adjustment of the projects of receiver and emitter.

It is given concrete form by the industrial arrangement negotiated between the parties. Technology transfers become possible if the strategies concerned can find a zone of compatibility. The decision process of the companies aggregates technology transfers into the totality of business activities (139).

The arrangements will vary according to whether the proposed technology transfers are to occur with or without intersecting operation spaces (clientele, investment, information) for receiver and emitter. The main types of arrangement are: licensing agreements, technical assistance agreements between firms, sub-contracting (direct between autonomous units, between the subsidiaries of multinational firms by their subsidiaries), compensation agreements, coproduction agreements, contracts with engineering firms, international co-operation for trading purposes, international, bilateral and multilateral co-operation.

These various arrangements may be felt to reflect a recognition of the respective strengths of the partners. The arrangements reflect a more or less pronounced scale of autonomy for the receiver,of asymmetries, and more balanced positions.

Such power relationships come into play with the setting up of a single technology transfer project.

A weak receiver, with little information about alternative technologies, will be strongly influenced by the emitter's project.

The organisational networks set up for technology transfers also reflect these power relationships. Emitter or receiver may dominate the network of the other agents involved.

Emitters are often interlinked through public or secret agreements (among owners of processes, materials manufacturers, engineering companies for example).

The axiomatic of the social forms of technology and active units thus makes it possible to construct a less incomplete *model* of technology transfers. The two sets, "activities" and "agents" are linked by an interactive sun-system, "types and channels" for transfers.

The "activities" set turns more towards the use value of the technology, the "agents" set towards its exchange value. It is where the two sets intersect that they can combine.

Whether or not the various channels are used depends upon the social decision of the partners involved.

The logic of resorting to these channels also obeys another still underexplored aspect, of the "order" of technology transfers. Their "length" expresses the emission durations necessary for technology flows, which varies according to the kind of transfer in question. The order in which technology contents depart and arrive, and consequently, the connexion of the channels between emission and reception surfaces, probably obey the logic of the various production systems.

A technology transfer "profile" would represent the shape of the project adjusted between emitter and receiver, the order in which channels arrive and depart, the elementary emission times for the various activities, deformations in the emission and reception surfaces, the configuration of agents involved in implementing it.

Algorithms could be established for the principal classes of transfer as a function of the production systems to which they are attached.

The model thus sketched (142) makes it possible to rectify certain common clichés about the ultimate purpose of technology transfers, a matter on which there is a great deal of understanding.

The predominant opinion of the last 30 years has been that technology transfers should be maximised as a condition for modernisation and growth. This was easily explained in post-war conditions, and the naive belief that any foreign investment, and therefore any associated technology transfer, was beneficial by nature. Experience has shown that this is not necessarily the case.

The integration envisaged in "international development strategy has increased the dependence and reduced the autonomy of the developing countries". Technology transfers have appeared as essential elements of dependence. The counterparts have proved particularly heavy. It was not just that the explicit costs greatly exceeded the first, which were only the tip of a huge iceberg.

Technology transfers led to overpricing, and among multinational subsidiaries and headquarters, fictitious book-keeping which permits transfer pricing.

Restrictive business practices accompanying technology transfers were felt in may ways to have even more serious consequences than overpricing. They consisted, in particular, of imposing many obligations upon the technology receiver, such as that the produce manufactured under licence must not be exported, raw materials must be procured from the licensor, in some cases the volume of production and sales prices for the licensee etc. (143).

However, experience also shows that many of these restrictive business practices did not occur when the strengths of the two sides were in balance. Industrial arrangements included counterparts of a different kind.

Weak technological interdependence modalities appeared as one factor in the structural ascendancy. Countries, active units, became aware that genuine development was incompatible with the chain of dependence-causing relationships. (144).

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(142) Deliberately simplified in the diagram "Education-Employment-Science-Technology" on page 10

(143) Possibility and feasibility of an international code of conduct for technology transfers UNCTAD 6th June 1974 Geneva

(144) For an analysis of these relations see P. F. Gonod - Conflit Coopération dans le transfert technologique - op. cit. ref. 6

Vigorous reaction on the part of developing countries and sub-regional groups led to an international debate over the conditions for international technology transfers.

Proposals to put these on a more equitable basis, and to apply rules of conduct for technology transfer, have been formulated and are under negotiation.

In the "struggle/co-operation" mix characterising composite exchange, the conflictual elements increased

"Technical diplomacy" now does its utmost to diminish these, and establish a re-evaluated form of co-operation.

The option for the strong interdependence modalities (145) in industrialised and developing countries alike, is to strengthen the decision-making power to selected technologies considered appropriate. This selection is generally so effected as to leave the receiver country of enterprise a maximum action space compatible with that of the emitter.

It was becoming clear that power relationships should be reintroduced into the economy of technology transfers, and that there could no longer a question of just developing these to the maximum; instead, technological content should be so incorporated as to modify the action spaces of emitter and receiver.

(1) The problems of the developing countries

The concept of composite exchange helps to cast light on the specific problems of the developing countries.

The international conflict observed in internation technology transfer conditions should not cause us to lose sight of its obverse - co-operation issuing from solidarities.

Direct foreign investment and other forms of technology transfer are not zero sum games. The apparently opposing criteria of the technological firm in an industrialised country and the receiving firm in a developing country may coincide. Reasons for co-operation among firms are grouped around a central criterion: maximisation of profit and minimisation of risks.

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(145) F. Perroux "Independance de la nation et Interdependence des nations - Auber Montaigne - 1969

It is possible for both parties to maximise profits even in cases of asymmetrical relations: the problem faces not only the licensor but also the licensee. He may be facing an almost monopolistic market and be able to draw exorbitant profits from the sale of what he produces under licence. These profits are the result of the production tariff, exchange control, and the lack of domestic investment funds, which limit competition . (146).

The various rents are compatible. The first consequence stemming from this is that in many developing countries, private entrepreneurs are not very interested in supporting their governments' efforts to reduce overpricing resulting from technology transfers.

For the technologically advanced firm, the risks in the transfer are the loss of manufacturing secrets and their use by competitors. For the underdeveloped firm, the transfer risk decreases owing to the proven reliability and availability of the technique. It is almost negligible in the case of obsolete techniques. In contrast, a technique which has as yet been little applied presents a considerable transfer risk. Conversely, its commercial availability is great.

The risk in technological creation, research and development is obviously higher than in technology transfer. The degree of risk will reflect the maturity of the innovation project. This means that risk scales can be compiled for technology transfer and innovation which will vary inversely with the commercial availability of the subject (9).

Solidarity in the minimisation of risks explains much of how those involved behave as they do.

In the first place, the acceptance of what are often obsolete technologies at high cost in the under-developed countries.

In the second place, the propensity to buy technology "packages" incorporating the patent licence, know-how, technical assistance, management and other "after sales" services.

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(146) J. N. Behrman - Decision criteria for foreign investment in Latin America - Council of the Americas 1974

The "turn-key" factory is the acme of the technology package.

It proves in many cases that if one "opens the package" there will be scope for including components, raw materials, equipment, engineering, design, secondary technologies etc. of national origin.

This policy usually encounters a stumbling block in the reluctance of emitter and developing country receiver.

From the standpoint of the emitter, the inclination is to promote repetitive projects in which licence, engineering and hardware can be sold as a single package. Standard projects make it possible to reduce costs (147).

From the receiver's standpoint, the entrepreneur generally prefers the security of the package to the possible snags in identifying other technical combinations.

Technology transfers in practice achieve solidarity in looking for a high return on capital.

Such solidarities appear at two levels: final consumption models, and the proportions of the factors of production.

Final demand is largely induced by the predominant consumption models. Ripple effects operate among classes: from the style and consumption levels of the rich classes in the industrialised countries to the rich classes in the poor countries, with an upward attraction for the more prosperous petit bourgeois groups in town and countryside. Though there are sometimes notable differences, the relatively poor in the rich countries and the poor in the poor countries are also pushed towards the dominant consumption models. Supply exerts the push and technology follows.

The dominating cultural models teleologically influence technology transfers. Supply is induced externally, but also internally.

In a developing country, the local market is often invested from within by foreign firms and affiliates, which fashion the sales space. Upstream and downstream, ripple effects and dominances occur.

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(147) Jacques Hertz - Stratégie du transfert technologique, aspects commerciaux - Compagnie Française pour la cession des licences Paris, October 1975

(148) Roland Lantner - A propos des phénomènes de pouvoir: une analyse de la structure des relations entre groupes industriels Economie appliqué - ISEA Archives, Volume XXIV 1976

Products and technology condition one another reciprocally in the mass production system. International technology transfers propagate the product cycle (149), but propagation of the product implies technology transfers in the process of internationalising production (150) marked in particular by delocalisation of the point at which added value is created (151).

The technology with which to manufacture such products is mainly available from the large frims which have created or captured it. The project of the private or public undertaking in the weak capacity country is oriented, at the outset, by technological reference models.

The predominant final consumption models form one of the extrinsic features of the technology transfer system. The technology transferred has as its content the intrinsic features of the technological models of the emitters' "reference class".

Among its recipients it reproduces the conditions under which capital earns a return. (159). This return-on-capital process follows a trend line common to that of the capitalisms in the industrialised countries: economy relative to the labour force (153).

Since developing countries usually have a plentiful supply of manpower, though there are exceptions (154), the transfer of "capital-intensive" technologies does not substantially help to reduce unemployment, and may sometimes even aggravate it. In the industrialised countries, the intensification of capital and change in its organic composition exert compensating effects. The relative diminituion of manpower in certain sectors is more or less compensated, at least in periods of economic upturn, by a transfer of jobs to the capital goods producing sector.

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(149) P. Vernon - Les Entreprises multinationales, Paris, Calman Levy 1974

(150) C. Palloix - Les firmes multinationales et le procès d'internationalisation - Maspero 1973

(151) C. A. Michalet - Le capitalism mondial P.U.F. 1976

(152) Using Karl Marx's outlines for capital cycles, it can be observed that the majority of transfers occur during the trading capital cycle, in the money-merchandise transaction where money capital is converted into productive capital.

(153) Reduction in the quantity of manpower per unit produced is the principal function of technical progress" Farhad Rad Serech Technologie et industrialisation. Reflexions sur l'experience Iranienne. International Economic Conference on "Economic choice of technologies in developing countries" Tehran, Iran, 18-23 September 1976

(154) Some of the oil-rich arab countries, Iran and Saudi Arabia for example, are a-typical, with abundant capital but a comparatively scarce labour force.

In the absence, or weakness, of a capital equipment industry, such compensation cannot occur in developing countries.

In these circumstances, the technology transferred reproduces the proportions of factor availability in the industrialised countries, but for only part of the social process. Hence the accentuation of a fundamental asymmetry.

Technology also transfers the division of tasks in the work and organisation. "Scientific work organisation techniques" form part of the "technology package". They are generally a consequence of the logic of the intrinsic features of the technological system. This is why they appear to spread without undergoing any essential modification throughout the various social regimes. The fragmentation of science and technology is prolonged in the organisation of production for most workers, into work on only a tiny part of the whole. The demand for job-enrichment in reaction to this will probably require a reorientation in work organisation techniques (155).

Some concessions are possible, but it is doubtful whether substantial change can be brought about without shaking up the very structure of the objects and the technological system. If this is to be done, it will depend essentially on mastering technological development and its social control in the industrialised countries themselves.

The transposition of labour tasks and discipline to countries in which lifestyles and manners are forces of resistance to the introduction of cultural models may occur in three ways.

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(155) Michel Louis Debatisse - L'enrichissement du travail: également un dilemme pour les pays en voie de développement - Mondes en Développement No. 15 1976

The first is internal imposition. The economic need to work for those who have no other means of subsistence is usually enough.

The second is to prepare individuals for the tasks they will be expected to perform.

The third is to adapt such tasks ergonomically to the individual with special physical and cultural features (156),

The two latter ways, and especially the third, are still the exception.

(ii) Intermediate technologies

The disturbance caused by the transfer of inappropriate technology to developing countries, to individuals, to the alleviating of unemployment and under-employment, have led to the formulation of the counter-policy of "intermediate technologies".(157).

These ideas, originally confined to the problems of the developing countries, have been put into a new relief with the energy crisis and growing awareness of environmental deterioration. In opposition to the "hard technologies", cause and effect of uncontrolled growth, it is proposed to apply "soft" technologies which consume little energy, generate little or no pollution, and are less disfiguring to man at work.

Soft technology, taking the place of hard technology, would shape another type of civilisation. Reducing the waste of non-renewable resources would - and will - lead to the conception and spread of other technologies. This assumes that the value conflict at the level of the cultural model is resolved by the choice of proper living conditions for our descendents in preference to desires for immediate gratification and power.

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(156) Sylvère Seurat - Réalités de transfert technologique, 1976.

(157) E. F. Schumacher - Small is beautiful - op. cit. See also Antonio Marques Dos Santos - Contribution à la critique du concept de technologie intermédiaire - Tiers Monde - January-March 1976

Concern for the environment is a unifying force, and in those countries where it has gathered strength it has brought new sociological configurations and growing international co-operation into being.

The problems of altering the respective contents of capital and living labour transferred with technologies to the developing countries cannot however be put on the same footing as the ecological reaction.

While there may be a wide social base for ecologically oriented policy in the industrialised countries, the base for intermediate or labour intensive technologies is very narrow.

The entrepreneur in a developing country is not usually interested in adopting a technology which uses more manpower. In the first place, because the growth line for the market economy and technical progress is in economising on manpower. Then, because labour-intensive techniques are not produced in the industrialised countries, and he prefers the safety of the technology package to combinations on which he may not be able to rely. Management of a large workforce is harder than programmed management where the minimisation of personnel makes transformation and input-output forecasting less unpredictable.

Finally, the workforce is not as docile as the machinery: it is organised, puts forward claims, goes on strike. For all these reasons, the entrepreneur can have no real interest, under modern production conditions, in preferring to maximise the labour input.

Intermediate technologies would in fact imply other production modes, ruling out mass production and large production units; there would have to be small, locally-oriented markets, small-scale production of more durable products. All these conditions could at first sight apply to many of the developing countries were it not that the internationalisation of production, and solidarity in seeking a return on capital, have overturned the position.

Industrial and engineering management, even in nationalised firms, are largely conditioned by training, usually abroad, by the technical levels and solutions of the industrialised countries. Not to use the most sophisticated techniques is perceived as frustrating and a loss of prestige. Thus the engineer is frequently a further source of opposition to the demand for technologies which, if not "intermediate", would at least be more appropriate to local needs.

The mass of unemployed, underemployed, and industrial wage earners in the developing countries would theoretically have an interest in the application of new technological policies. But it is not they who make the decisions. Nor, on the whole, have they the information which would enable them to become aware of the importance of technology in development, and how it should be oriented to favour social demands.

The rural masses are in a better position to express the needs of agrarian communities directly. The agricultural producer in a developing country is a less unidimensional man than the uprooted proletarian in industry. Awareness of needs is formed more easily than for the industrial workers in the developing countries. The passage from needs to demands does not usually require "points of conversion" to combine and reduce needs. (158). The direct form of expression makes it possible to design inexpensive technology projects for rural communities (159). They may be so shaped as to possess sufficiently powerful extrinsic features to limit the input of technologies escaping the characteristics at work in the international technological system.

In the last analysis, the social base for the transfer and creation of labour-intensive industrial technologies to the developing countries is usually a small intelligentsia within the government machine and the university. This is sufficient to arouse international interest, but not, so far, to modify real choices.

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(158) On the notion of "points of conversion" see D. E. Easton - A system analysis of political life - University of Chicago John Wiley & S. 1965

(159) Appropriate technology - Problems and prospects. Under the direction of N. Jequier OECD Development Centre, 1976

(iii) The regulation of transfers

It would be unrealistic to expect the developing countries' problems in this area to be solved by spontaneous mechanisms.

An international code of conduct for technology transfer could facilitate the elimination of restrictive business practices, but it would not eliminate the asymmetries and the conflict/co-operation characterising technology transfers.

Their regulation is therefore a complex task, in which the developing countries may encounter two dangers.

The first is of remaining at the level of declarations of intent, or even of legislation which remains unenforced due to lack of an internal logistical base (160).

The second is to create an ineffectual bureaucracy in an area which so far has implied only direct relationships between firms, private or nationalised. For selective regulation of technology imports to be effective, it must be fitted into the framework of the mechanism, the country's engineering, at the interface between firms and the State.

Control over the import of technology is perhaps a necessary condition but it may not always be a sufficient condition to bring about fresh technological orientations. It is brought to bear at the end of the process of adopting and negotiating for technologies. But it is not of a nature to modify technological choice, and it is the choice which is decisive (161).

These observations suggest two important consequences;

The first aim of a country aspiring to implement strong independence modalities must be to exercise a predominating influence over technological choice at the earliest, pre-feasibility stage of an industrial project.

For such choices to be made intelligently, adequate information and a methodology for evaluation are prerequisites.

The operational information which a developing country requires to decide upon major investment projects and enter new branches of activity is a combination of technical, economic and commercial information (TEC information) (162).

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(160) The juridical illusion has weighed adversely in the effective implementation of new technological policies in Latin America over recent years.

(161) Pierre F. Gonod - Matériaux pour de nouvelles politiques de transfert technologique - Tiers Monde - January-March 1976

TEC information should contain information not only about technology, but also about the economics of the various technological processes and the conditions under which they can be available commercially. It should provide information about existing links between technology process proprietors and the various intermediate transfer agents. Such information is not available in the current literature and requires to be built up.

It should be elaborated in accordance with they way it is to be used to evaluate and adopt technologies. Evaluation methodology reacts back upon the actual make-up of useful information, which is information with a high "structural content".

It should permit the calculation of costs within the structure of local unit prices. In point of fact, free information about technology costs rarely separates the quantities of inputs and outputs from unit costs. The information is aggregated, from "moment one", like much accountancy information. The one-dimensional levelling of information is one of the most serious obstacles to the exercise of discretionary power in technology selection.

TEC information should be so constituted that when processed it can provide factors to act as guidelines for the decision-maker with a technology transfer choice to make. The extraction of essential information about the factors governing the problem in hand, its classification into decisional variables and constraints, represent a new approach in technology assessment (161).

At this point, information enters into the power and decision play between the enterprise and government institutions. It creates the elements for negotiation within a zone of decisional influence variables, and joint programmes to eliminate any constraints.

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(162) German Framinan, Pierre Gonod, Carlos Martinez Vidal - Informacio para la transferencia de tecnologia (ponencia prestada en el trigesimo octavo Congreso Mundial de la Federacion Internacional de Documentacion) Comercio Exterior - Banco Nacional Mexico - October 1976

A technology assessment method also sets the scene for negotiation within government institutions. It forces all concerned to reduce the gap between the level of general criteria representations - usually not operational - and that of their effective implementation. It provides a practical pivot for economics, policy and technology.

A technology assessment method, based on the participatory processing of variables according to their respective power centres, is a way of constructing a national technology "policy-making" function.

This is the prerequisite for ceasing to regard technology as something that just has to be accepted in development, and for promoting it, instead, as a variable, gradually fixing explicit technological objectives.

The regulation of technology transfers in developing countries therefore requires organised mechanisms, whose shape should reflect the special features of the countries concerned (161) (9).

(iv) The structure of transfers

By analogy with the analysis of the education system, we may endeavour to summarise: (a) the extrinsic features of the technology transfer sub-system (163); (b) the data lacking for an understanding of its structure (164).

The extrinsic features of the technology transfer sub-system are as follows:

I) The relations of its elements are teleological.
Among emitters, receivers and intermediate agents, relations tend towards goals. The ultimate purpose of the transfers is to increase the action spaces of the parties. Transfer is possible if (a) there is at least oneasymmetry in the action space elements, (b) the respective goals can find a zone of compatibility within a given period (c) there is an adjustment, by counterpart, for the elements in a single project.

Solidarities with respect to the reproduction of capital, and earning a yield on it, are the extrinsic characteristic of the system which enables it to overcome the conflict-co-operation contradiction inherent in the composite exchange of technology transfers.

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(163) See p. 31 and 33: An historical, living and social system
(164) See p. 39 the pedagogical model, and 16 , epistemological notes

When the interdependence modalities are weak for the recipient, the project and the transfer modalities are in fact an expression of the goals of the emitter.

Similarly, relations between transfer and technological innovation are teleological. Transfer, as an output of innovation, tends to disseminate it. "Horizontal" transfer, as an input to innovation, tends to improve it or else, through some new technological combination, to lead to the appearance of a new "technical line" (165
(2) Causal relationships appear between production systems, on the one hand, and the transfer types and channels on the other. The latter are therefore subject to the twofold influence of causal and teleological relations. Order relations, linked to the logic of the production systems and activities of an industrial project, govern the flow rate of technological content in the transfer channels.
(3) Just as with education, (166), the paradox of technology transfer is that relations between receivers and emitters are not transfer relations in the algebraic sense. Whereas a biological system "empties" a reference class by transferring its elements to some other class, the same does not apply to part of the technological contents. The transfer of technology does not empty the content of the emitter into the reference class of the receiver: I in A - I in B does not equal zero in A and I in B but may equal I + I or (I+n) + (I + n').

By reference to biology, transfers in which the technology is not incorporated in a flow of capital goods -- i.e. the socialised, intellectualised and alienated forms -- take a process approximately resembling scissiparity.

Information does not exhaust its content for the emitter.

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(165) The activity of the "Scientific-technical Agencies" of the United States, in particular, tend to systematically encourage innovation by intersectoral horizontal transfers. See W. Henry Lambricht: Governing science and technology - Oxford University Press, New York 1976.

(166) see page 37

Information decays through the occupation of the reference class by other information. But even a decayed, obsolete item of information may continue to be emptied from one structure to another. Thus the developing countries continue to acquire and pay for obsolete information long since transferred by the emitter to the public domain in the industrialised countries.

(4) The assimilative capacity of the recipient is a function of: (a) his primary "representations" resulting from the general education he has received (167); (b) the structural content of the information procured at the various stages of the transfer, and in particular, during the preparation of the project and the selection of technological alternatives (168); (c) what learning he has received with which to memorise the information

(5) The intrinsic tendency of the transfer system is to reproduce itself identically. This derives not solely from that of cultural models among themselves, the effects of domination, but of the standardisation, in the advanced industrialised countries, of projects whose intrinsic function is to reduce costs.

(6) The technology transfer sub-system, like the education system, cannot undergo major change unless it receives strong social commands creating a counter, or other, conformity.

A distinction must be made between changes resulting from the relations of the parties to the composite exchange, the definition of other "rules of the game", and those resulting from actual domination of the technical system.

The first can be greatly facilitated by technical assistance redeployed to fortify the weaker negotiating position.

The second take longer to bring about, taking place at the heart of each society, and mainly in those of the advanced industrialised countries. Changes of this kind can only be effective if the system is also "operated" from within: at the level of technological training and culture, technical creativity, internal and external social control over the enterprise. As has been noted (169) to be able to contemplate how a system may evolve requires an understanding of its total real structure at a given moment (19). Data which can be regarded as known are I (affirmation of the existence of reference classes), 6 (affirmation of the existence of relations between reference classes) whereas data Nos. 7 (fundamental type of relations between reference classes, group order etc) remain to be explored. It will be recalled that these three data define the "relational structure (170).

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(167) see pages 32, 42 and 43.

(168) see pages 82 and 84.

Data No. 2 (number of reference classes) are known as a first approximation and are the subject of the hypotheses described above for sub-sets constituting the technology transfer model. Data No. 3 (definition of each reference class, intrinsic and extrinsic features) are fairly well known for the exchange value side of technology. But paradoxically, the use value side has been less studied. Transformations of scientific information, technical innovations, technical objects, production systems, inter-relations, the intrinsic and extrinsic functions of the various levels are problems remaining to be explored.

Social mastery over technology is limited by the absence of fundamental knowledge.

The typology, general organology and mechanology for technologies are essential instruments whichwe lack.

Data No. 4 (number of elements in each reference class) are unevenly known. While they are available with sufficient precision for agents, activities, channels and types of transfer, they have not been subjected to systematic and typological analysis for technological modules.

The same applies to the ordinal data for the relationship between channels and production systems, which could provide a basis for an algorithmic approach whose operational scope will be immediately apparent.

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(169) See epistemological notes, p.16.

(170) See p.17.

2 All in all, we have some way to go before we can understand the "total structure" of the real system of technology transfers.

When we really look into this, our relative ignorance is not so much about transfers as about the technology system.

Bearing all this in mind, a less incomplete definition of technology transfer may be tentatively offered: "a complex social process resulting from interaction in the composite exchange of the use values and exchange values of technologies, the mix of free and reciprocal transfers of utility and power relation. A set, according to which technological contents are incorporated in production systems and are directed by the activities of various agents, according to the channels and arrangements, to modify the action spaces of emitting and receive units, which are usually unequally active" (43).

E. THE SUB-SYSTEM OF TECHNOLOGY-EDUCATION INTERACTIONS

The interactions within the "science-technology-education" complex have been analysed in the preceding chapter. At this point we shall merely pick out the key points, the real nodes of the system. But first, we must return to the question of employment, whose position in the interaction between education and technology we were able to anticipate.

(1) The mediatization of employment and occupational tasks

The employment model (171) comprises reference classes: nomenclature of occupations and trades, branches of activity, enterprises, specific tasks of enterprises, personnel status, qualification level, remuneration level, job specification, recruitment, supplementary training.

The employment sub-system really deserves a study to itself. We shall therefore confine ourselves to those aspects which affect its inter-relations with the education and scientific-technical systems.

The input to the employment sub-system consists of those leaving the education system. It provides some entrants with supplementary "on-the-job" training. The majority of individuals will be in enterprises attached to production systems. Employment is thus "pulled" teleologically by the production systems.

But it is subject to other complex relations. The outputs of the scientific-technical system, scientific knowledge and technological innovations operate, through the function of scientific progress, upon the nomenclature of professions and trades, stamping an evolution on the social division of labour and the delimitation of tasks.

The cultural model influences qualification and remuneration levels teleologically. It projects a scale of values, which exerts an effect upon the classification of workers.

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(171) See page 10 and the caption on page 12

The education system, at the level of examinations, certificates, diplomas, and their associated social status potential, has an oriented and interested relation with job specification.

The job nomenclature spreads through the branches of activity and firms, where it distributes itself into specific tasks.

It is at the level of the firms and branches that technical innovations penetrate, through horizontal and vertical technology transfers.

Employment is the point of departure for two feedbacks. The first is produced through the division of the tasks of labour, and exerts an influence on the orientation of technical invention. The second is the reaction exerted by individuals trained for specific tasks upon the cultural model itself.

The relations among nomenclatures, branches, firms, the tasks and status of personnel, qualification and remuneration level, and job specification appear to condition one another reciprocally, forming a closed loop of causalities. Any change in one element brings about an adjustment elsewhere. The system regulates itself by constant correction. But as it is operated upon externally, by the scientific and technical system, technological innovation and transfers, the education system which provides it with individuals having specific knowledge profiles and qualifications, a social exchange potential sanctioned by examinations and diplomas, the employment sub-system becomes destabilised. This instability leads, in turn, to readjustments among all the elements constituting the internal reciprocal causality loop.

When there simultaneously occur an influx of entrants to the educational system, due to demographic trends and social demand for education, and a setback in the employment market, education and employment system alike enter a crisis in which each has repercussions upon the other. Education, in disarray, no longer knows for what, and in what numbers, to prepare its pupils. The young, unable to find work, together with those of all ages who feel that their status does not match the training they received, turn against the education system, or cease to provide it with the support necessary for an education consensus.

Friction among the three systems, scientific-technical, educational and employment, liberates an intense social energy.

These theses suggest some comments:

(1) The nomenclature for the branches of activity is both an abstraction and at the same time, an institutionalised reality. "Branch" or "sector" are intellectual categories. Other groupings could have been imagined. They nevertheless possess a conventional character (172). The branch corresponds to a criterion of utilisation, and not to a technical essence. One and the same technical essence crosses various branches.

(2) The trade and professional nomenclature evolves, ultimately, in response to technical progress, though with a delay due to the drag exerted by the status and interest pressures, and the previous qualifications of socio-occupational groups.

The influence of socio-occupational groups and specialised forms of education creates a tendency towards diversity through the reciprocal causality of status upon nomenclatures. Technical progress provokes an opposite tendency, twoards a reduction in the headings. But the massive operating function of technical progress is stronger in the long run. (173).

The content of the nomenclatures remains, nevertheless, an approximate reflection, though sometimes a remote reflection, of the content and evolution of technical progress (174). Hence the serious difficulty in defining tasks so that they closely match the evolution of functions, and their proportions, under the influence of technological progress.

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(172) For example, the grouping, in the agriculture branch, of such different systems as intensive cereal or horticultural production, extensive livestock breeding, the industrial production of pork and chickens, cover what is in reality an incongruous mixture.

(173) Radovan Ritcha and his collaborators point out, in Civilisation au carrefour (Ed. Anthropos 1969) that the trade nomenclature of the US Department of Commerce has passed from several thousand to about three hundred.

(174) Auerhan illustrates the correlations between the stages of technical progress and work functions (Technika, kvalifika vzedělani - Prague 1965) quoted by R. Ritcha.

The tasks defined are, morever, far from being homogeneous within firms in the same branch of activity (175).

(3) The education system exerts another type of action upon employment. It will be recalled that all education has relations of order (the order in which knowledge is acquired) and of group (education families, composition of curricula). Order and group combine into levels, i.e. thresholds. These assume that to learn to particular grades takes approximately the same time. But this distinction between cycles does not solely reflect the specific requirements of the act of training. "It reflects much more the habits and choices of society". "...the logic of a nomenclature based on the constituent elements of employment is very clear: it will be possible to group jobs differentiated by qualities easy to acquire, and those which have it in common that the qualities necessary require more effort..." "... it will be observed that a job nomenclature based on the idea of homogeneity, or easy of change, or of mobility within each heading, is in fact based on the concept of how long it takes to acquire supplementary qualities. Now this depends on how training systems are organised, and what pedagogical methods are used. Which means that a nomenclature claiming to be objective is in fact inseparable from the social organisation of education." (175).
The building up of a nomenclature consists, in theory, of arranging the elements which form jobs with respect to the constraints of how long such qualities take to acquire and in what order they are acquired.

This analysis makes it possible to identify another relational loop: curricula and pedagogical methods affect the job nomenclature, but are themselves operated upon by segmented scientific and technological knowledge and by the cultural model.

A direct action variable can therefore be sought in the education system.

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(175) J. Vincens - Les prévisions par professions - Revue économique, July 1969, La prévision de l'emploi, P.U.F 1970.

"We could therefore reverse the problem and see whether improved training systems might not in many cases make it possible to alter the nomenclature; if the time taken to acquire this or that quality could be reduced, it would be easier to regroup the job requiring it under another heading with jobs that did not need it" (175). Regroupments of this kind influence occupational mobility. The scope of this analysis for technical education will be evident.

The integration of technologies in curricula (176) would make it possible to reduce the time needed for education and regroup occupations. The mobility which would thus be increased would make it possible to implement one of the aims of polytechnical education: that one should be able to change one's activity over the course of a working lifetime. But on a slightly different basis: by broadening the very definition of the occupation.

(4) The relations between employment and the eduation system pose formidable problems to the education planner. Evolution in the employment structure of a branch involves two sorts of change: changes affecting the job structures in the firms (internal job structure) and those affecting the distribution of firms within the branch concerned (market structure).

The two structures may evolve in parallel or in opposite directions, and the job structure at branch level agregates such changes. Tasks may vary for similar firms in the same branch, and long-term forecasting in their respect, which depends upon a number of parameters, proves impossible. This can only be based on functions and function levels (31). Analysis of the trend for job structures within the branch is a matter linked to the analysis of productivity and the spread of innovation. In heterogeneous branches, where there are considerable differences in size, technical level, productivity, the characteristics of the upper part of the sample may prejudge the future situation of the branch as a whole. The time it takes for the results of leading firms to spread through out the branch depends upon the speed of technology transfers by imitation within it.

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(176) See: The integration of technologies pp. 80 to 81

But during this time, other forms of technical progress may intervene, precipitating company mergers or offering fresh chances of survival to those threatened. The scope of the forces set in motion depends upon the intrinsic and extrinsic characteristics defining the functions and laws, if any, governing the evolution of branches.

For example, in branches which lend themselves to the internationalisation of production, the setting up of a subsidiary by a multinational usually is a disturbing element for the existing technical and economic structures. Branches behave differently towards technical progress. Some advance through exogenous contributions (the food industries for example) or are heavily dependent upon such contributions (iron and steel) while others, such as electronics, advance endogenously.

The capture of exogenous progress, and the generation of endogenous progress, create new combinations (in petrochemicals, for example), which spread through other industries.

It is the endogenously advancing branches which bring about "innovation by invasion" i.e. the penetration in force of the technology of one sector by another. The receiving sectors will present a greater or lesser degree of capacity to resist, of porosity, and of structural readiness to be permeated.

Technical progress thus modifies the tasks, and their proportion, in ways which differ according to branch and production system.

The laws of this movement remain unclear. The concept of "law" does not here introduce any historical fatalism, but a tendency law, resulting from human activity, facilitated or impeded by human groups.

Thus the socio-occupational reactions of defence and advancement pivot within this complex movement.

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(177) André Strarapoli - R&D and technical progress - L'innovation dans les industries agricoles et alimentaires - Le Progrès Technique - No. 3 September 1976.

113

In those branches with heavily concentrated firms, and a strongly unionised workforce, the employment level is not established as a mechanical consequence of the trend for production and productivity. Employment guarantees have the effect that for those branches, productivity is as much a resultant as a conditioning factor (178). The present economic recession in the market economy countries reveals differing adaptations for employment as between nations and sectors, showing the importance of socio-occupational group organisation as a factor in the outcome and rationalisation of crises.

This is why the first projections by economists starting off with educational planning appear naively **mechanistic** with hindsight. (30). They have been inoperational mainly through their failure correctly to apprehend the rich complexity of technical progress, and because they assumed a society without classes, conflicts, active units with different powers.

The present dilemma can lead to two extreme attitudes.

The first is to call for school and university programmes to match employment forecasts. This is the "technocratic model" of education, presupposing an economy planned to to the maximum extent. (31) It has the merit of offering some prospect of advanceme to those presently at a disadvantage. It implies a domination and social control of science and technology which, as we have seen, remains a long way off.

The second is to suppose that "the outlets can be whatever society wants them to be. Translated into more precise pedagogical terms, this meass that education can be organised, and develop, in accordance with the a policy belonging to the education system itself, which conducts a constant dialogue with the whole of society and not just the sectors of the economy"(31).

This pedagogical model can be a "humanist model" in the noblest sense of the term (not in the sense of a class culture). It can become a "libertarian model" if, through going too far, the ultimate purposes of education are left wholly to the discretion of the individual teacher, who could modify the programmes to match his own personal ideas about man and society" (31).

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(178) Pierre Gonod - Mesure de la productivité dans les industries du charbon et de l'acier - Luxembourg CECA - 1964

Expressed still more cuttingly, the alternatives might be: to adapt education and men to the tasks of production, or adapt the tasks to match the education they will have received, and a certain conception of what man should be.

The dilemma is not so simple. Indeed, if it were posed solely in these terms, there would be no chance of a solution to suit either of the extreme attitudes.

Taking "a plurality of phenomena" into consideration makes it possible to envisage other solutions (31).

In contemporary reality it is true that education has difficulty in catching up the evolution in techniques and employment. The rotation times are different. Technical change is more rapid than change in employment. Educational adaptation is the slowest of the three.

But as we have seen, the social organisation of education is what shapes the nomenclature of occupations, the qualification levels, and who has what social status. There is a slow but powerful induction at work here. And a whole system of subtle interactions connecting the elements of employment, education and technology.

What we need to do is to identify the keys.

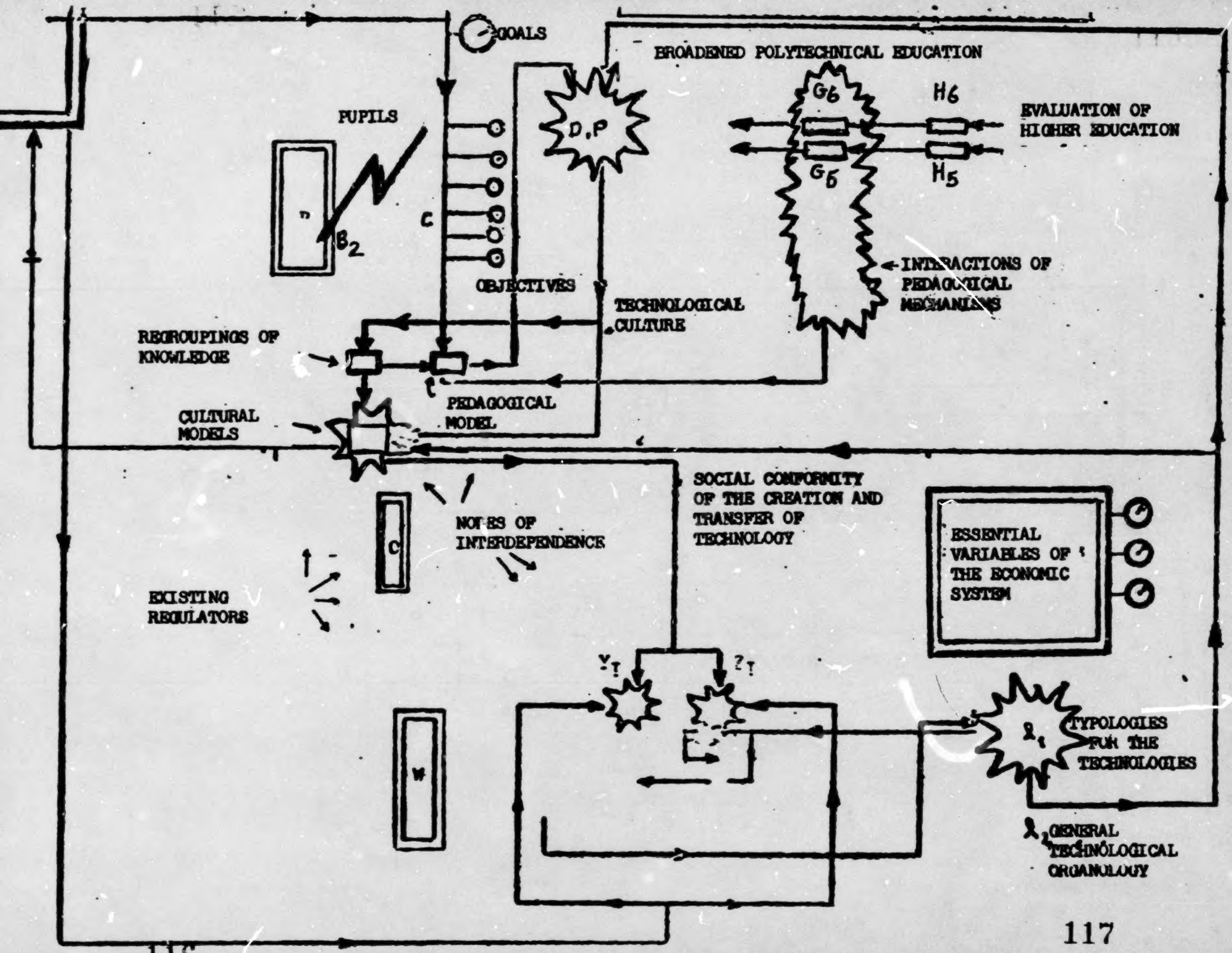
(2) **Identifying "nodes" in the interactive systems.**

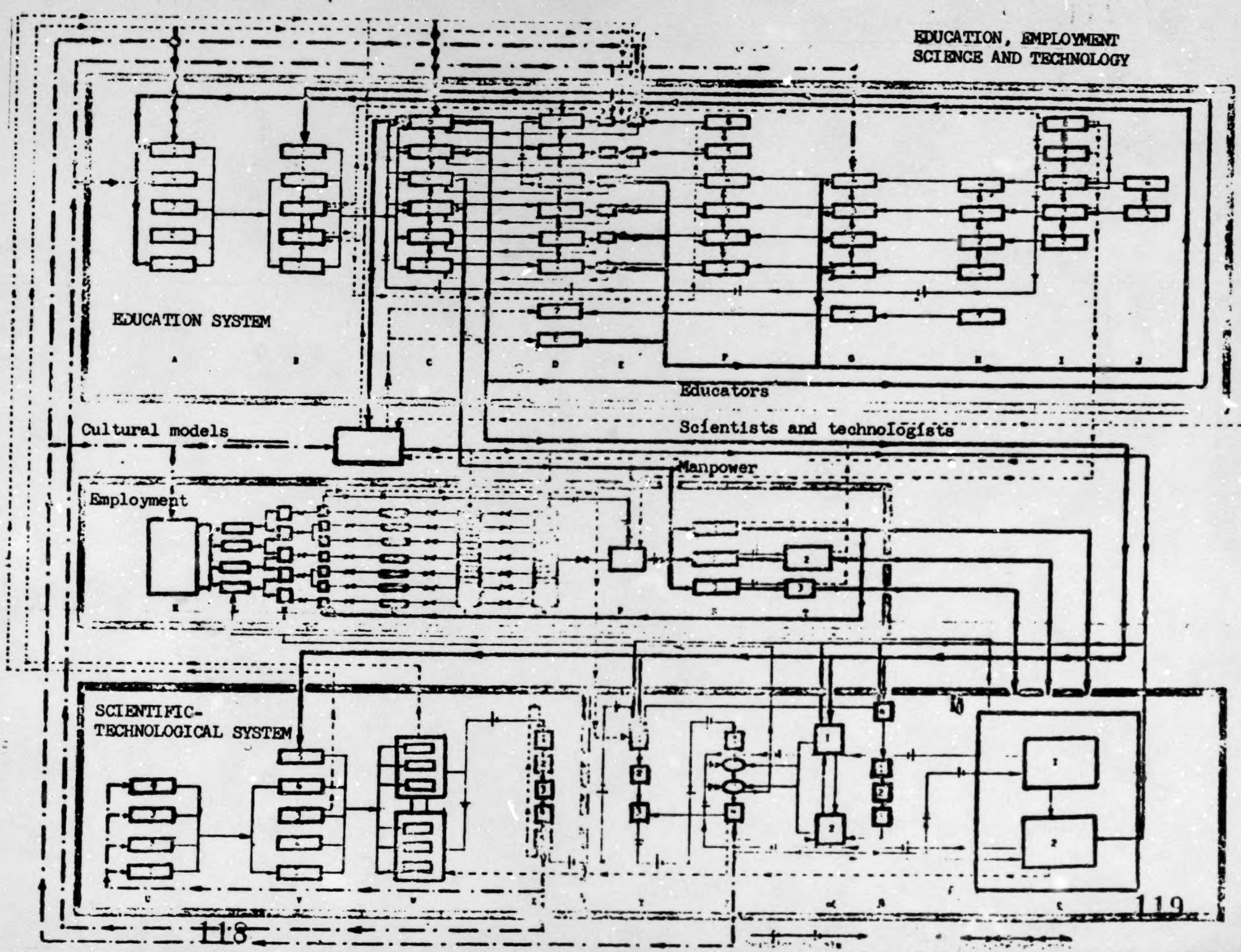
Throughout this work we have been doing our best to describe the principal relations between "reference-classes", the elements within these, the major causality loops between the systems under consideration, and the presence of interactive systems.

There is no need to go over that analysis again, but we shall try to draw out its implications to see how corrections might be effected.

The diagram "Elements of reguations and control" symbolises the improvements and actions suggested.

It is designed to be read as though superimposed upon the "Education-Employment-Science-Technology" diagram.


GOALS
BROADENED POLYTECHNICAL EDUCATION
D.P
G6
H6
G5
H5
EVALUATION OF HIGHER EDUCATION
PUPILS
B2
C
OBJECTIVES
INTERACTIONS OF PEDAGOGICAL MECHANISMS
TECHNOLOGICAL CULTURE
REGROUPINGS OF KNOWLEDGE
PEDAGOGICAL MODEL
CULTURAL MODELS
SOCIAL CONFORMITY OF THE CREATION AND TRANSFER OF TECHNOLOGY
C
NODES OF INTERDEPENDENCE
ESSENTIAL VARIABLES OF THE ECONOMIC SYSTEM
EXISTING REGULATORS
Y_T
Z_T
W
λ_1
TYPOLOGIES FOR THE TECHNOLOGIES
λ_2 GENERAL TECHNOLOGICAL ORGANOLOGY


EDUCATION, EMPLOYMENT
SCIENCE AND TECHNOLOGY
EDUCATION SYSTEM
A
B
C
D
E
F
G
H
I
J
Educators
Cultural models
Scientists and technologists
Manpower
Employment
SCIENTIFIC-
TECHNOLOGICAL SYSTEM
U
V
W
X
Y
Z
α
β

From this it will be possible to identify: the relations to be constituted or modified to influence the systems and penetrate the causality loops (indicated by arrows), the existing regulators (indicated by double rectangles) and nodes of interdependence (indicated by broken lines).

Each of the three systems under consideration is traversed by at least one major internal circular relation. Education by the self-training of teachers. Employment by the loop combining status levels, qualification levels, and job specifications. The scientific technical system, by the loop for the segmentation of different types of knowledge and institutions.

There are other internal loops: for example, the one between scientific and technical knowledge, the Research and Development mechanism, that of technology transfers, production systems.

But the systems are interlinked by numerous relations .

The most important is the one linking science and technology institutions to educational instutions, scientific and technological forms of knowledge to educational curricula and programmes, scientifi and technological forms of knowledge, cultural models and technical objects to cultural models.

Cultural models, in turn, operate upon the elements of the employment structure, the creation and transfer of technology. With technology transfers, employment structures and cultural models are projected onto the recipient.

Technology transfers and innovations operate in depth upon the employment elements. The techno-economic production systems draw the full set of other elements according to the logic, on the one hand, of the social structures and on the other hand, the logic of the technology.

As we have seen, there are many other relations which call for a more detailed description than in the above schematic summary.

These relations are of order, teleology, reciprocal causalitie and feedbacks. Thus, the major loops bring relationships of differing natures into association.

Each such relation operates at its own speed, which doubtless varies according to the society concerned. Some can be subject to measurement (179). All this accounts for the complexity of this essential part of the social system.

The static description shows up, though in simplified form, the great variety of the model, but the system is dynamic, everything is evolving and at different speeds.

This system of systems contains some formidable contradictions.

At the level of the education system, the main contradiction can be seen between the teleological character of the relations and functions of the education system and the absence of a system of finalised objectives.

At the level of the scientific-technical system, the main contradiction appears between the disintegration of scientific and technical knowledge in all its forms and the objectively integrating function of technologies through technical objects.

At the level of the technico-economic system, the main contradiction concerns the social nature of scientific and technological knowledge and their appropriation by private enterprise.

At the level of employment, these contradictions project themselves in the conflict between the dynamism of evolution in technical progress and the regulatory action of socio-occupational groups, between the tendency to shorten the nomenclature of skills as a result of the logic of the technical object and the proliferation of statuses arising out of the segmentation of curricula, the "status" conferred by examinations, diplomas and occupational specialisations and, in the developing countries, by structural diversification.

Cultural models, the principal regulators of the whole, are being destablised by the crisis in the education system and the force with which science and technology are penetrating the advanced industrial societies.

The information revolution is creating, outside education, a powerful source of selective information (180).

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(179) In particular, the application of algorithms to instruction.

(180) See page 53.

The school has lost its monopoly of cognitive information of the kind with which to modify the previous configuration of representation. This inevitably leads to change in the requisite pedagogical content and in pupil/teacher relationships. On the whole, education systems have been reacting to this challenge by a response of the same nature. Taking up the same terrain, they are condemned to aggravate their crisis. The extension by adjunction and juxtaposition of disciplines brings about a disorderly flood of information.

Through failing to regroup the various kinds of knowledge, education systems have been proving less and less capable of procuring the kind of information which has a high structural content and would make it possible to organise the totality of the information received, from without and within. They are threatened by gradual disintegration, especially at the top where the cracks are less visible.

The individualisation of knowledge, a profound need in the development of the specific individual, cannot any longer be satisfied by multiplying pedagogical curricula to infinity. This tendency, attached to the "humanist pedagogical model", (31), combined with the disintegration of scientific and technical knowledge in the crisis conditions of the education systems, introduces another internal contradiction.

At present it has a disaggregating effect, irrespective of its human justification. It can receive only a derisory response when education is crumbling up into fragments.

The dialectic of the individualisation presupposes, first, that there are forms of knowledge integrated into the education system and then, or at the same time, that there can be responses from a flexible and infinitely diversified network outside the institutional education system.

In the regrouping and generalisation of knowledge, that of technological education has a pivoting rôle. It enables us to act upon the trouble spots in the complex of systems.

The integration of technologies, the recasting of curricula are the departure points for new causal loops.

Pupils acquiring broader and more structured intellectual fields will themselves later on produce knowledge models which re-organise mental space and are intradisciplinary scientific and technological innovators.

Re-organised knowledge models will operate upon cultural models.

The integration of technologies is the prerequisite for the "possession" of technology, the demystification of the mysteries of its nature, and its "democratisation"

The democratisation of knowledge in this way may permit the emergence of social commands for the creation and transfer of technologies. Technological culture, based on cultural models, would create, through successive levels of awareness, a counter-conformity or a new social conformity, which would induce the mechanisms for the conception and transfers of technology.

The spread of technological culture, from the earliest years at school up to higher education, is a prerequisite for the domination of technology.

It will eventually call for major intellectual tools, a typology of technologies, a general organology, a mechanology, a common technological language. But we already have enough to make an approximate start on revising curricula without having to wait upon the formulation of a technological systematics.

It is most of all at the level of higher education that polytechnical education should be implanted or broadened. The technological systematics should gradually facilitate the regrouping of knowledge. The broadening of the intellectual field is compatible, through the pruning of non-essential information, the combination of knowledge forms, with the shortening of cycle durations.

Eventually the new "products" of the education system and the first regroupings of knowledge behind them should be able to produce new knowledge models which would give rise, in turn, to further regroupings of knowledge.

The new knowledge models would operate upon pedagogical models which were in the process of being constituted. But their existence presupposes that pedagogical research would have attained an operational level and most of all, that an education objective system existed.

Despite the progress brought about by the transfer and assimilation of a great variety of scientific knowledge, pedagogical research has two essential gaps. The first is connected with its disintegrated nature, associated with the absence of a general problematics, which is itself the outcome of the disintegration of knowledge and empirical research traditions. The second relates to the absence of evaluation of the higher levels of education. It is these levels which generally produce the ruling groups, in industrial and developing societies alike. So evaluation here could be expected to lead if not to self-criticism, at least to a critical reflection on the part of ruling groups or classes. These circumstances, over and above the technical difficulties, are not propitious for evaluation in higher education.

Fresh educational consensus are necessary in many countries to permit the formulation of pedagogical models. The education system cannot, alone, establish its own system of objectives.

It is up to the political system to play the key rôle in combining and reducing needs and demands, and in outlets. It is from the political system that an explicit system of objectives should stem.

The transformation is complex in itself. The political system is operated upon by the cultural model. The latter, it will be recalled, is not the ideology of a governing class but "an essential element of the cultural field in which class conflicts are formed". (46). It is within the framework of a society's common cultural field that the political system operates upon choices, according to its internal structure and the dominating ideology represented by those who exercise power. The transformation cultural model-system of objectives for education is therefore dependent upon class relationships. Antagonistic classes struggle to appropriate the cultural model. The orientation of the education system is the principal means of appropriating the cultural model.

The transformation effected by the political system depends upon numerous parameters: the differentiation of activities, cultural secularisation (23) (24) and within the latter, upon the levels of political activation (181) and on the autonomy or integration of the political sub-systems. (23) (24).

In the European centrally-planned economies, where the relative autonomy of the sub-systems among themselves is weak, the rôle of the political system in the transformation needs-demands-outlets appears different.

The ways in which countries are organised differ structurally, as do the ways in which this relates to the environment. It follows that the capacity for the needs-demands-outlets transformation varies from one country to another.

Analysis of the education system demonstrates, moreover (182) that for changes proposed and decided upon to become effective, they must also be operated upon from within. The political system can, and should, assign ultimate purposes and goals. It cannot define the precise objectives at each level without the participation of the education system.

In many countries disintegrating knowledge, rupturing educational consensus, challenge to the cultural model, mismatches between the training received and the profession being pursued, the intensity of the frictional forces generated by the contradictions in the education, technological and employment systems lead the political system to find refuge in merely advancing vague purposes to be served. The distance to be covered between the setting of final purposes and that of goals and objectives is therefore very great.

The political process can, through successive compromises, resolve neutralising conflicts and unblock the outlets. Its room for manoeuvre, how deeply it can affect the position, and how quickly it can do so will all be objectively limited by its own internal structure.

It is not possible however to regulate the education system without determining a system of objectives. Further progress is also required in the definition, even if only partial, of pedagogical models. This implies expanding, speeding up and integrating pedagogical research.

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(181) Guillermo A. O'Donnel - Modernisation and bureaucratic authoritarianism - Institute of International Studies - University of California, Berkeley 1973

(182) See pages 35 and 39.

Mastery over technology requires the reconciliation of disaggregated knowledge and the integrating nature of the technical object. Formulation of a technology typology, a general organology and a mechanology would provide the fundamental knowledge for democratized technological culture. In the shorter term, technological knowledge could be regrouped through modifications to education curricula, and by the creation or broadening of polytechnical education at higher education level.

As the foregoing analysis has shown, this essential modification would introduce a new causality loop for knowledge models, cultural models and technological creation.

Domination of the technological system, like that of the education system, is only possible if it occurs both from without and from within.

Educational mastery presupposes the regulation of technological knowledge and production. Domination of technology presupposes mastery over the education system.

This, perhaps, is the most important conclusion of the present analysis. It has a great many implications.

III. PREPARING FOR THE 21st CENTURY

The "Education-Employment-Science-Technology" model described in Chapter II is a simplification and an abstraction.

As has been shown, we are still a long way from understanding the total real structure of the knowledge systems considered. The first conclusion to which this leads is that comparison of the existing and missing data would make it possible to devise long term research programmed oriented by an integrating problematics.

As has also been noted it is possible, if not probable, that none of the real systems within a political entity coincides with the pattern established here.

But it provides a point of departure from which to describe the existing systems. The further down the scale of development we go, the more reality will distance itself from the model.

This leads to a second conclusion: comparison of the abstract model and the concrete realities in each country would make it possible by detecting and measuring the gaps, to establish a configuration for the comparison between countries, their problems and needs.

Establishing a pattern for the system of systems in each country would require verification of the hypotheses regarding the existence of the reference classes considered, whether or not the extrinsic and intrinsic relations are present and what form they take. When these investigations had been completed it would be possible to bring out the design of the static model.

To make the model dynamic would require us to include data for the reaction times of the various processes. It is in this area that data are liable to be scarcest. Nevertheless, with what is already known some progress could be achieved. Hypothese about the "major circular loops" could then be reformulated more specifically. We could try to identify possible trend scenarios, and their associated conditions and means of action.

This would doubtless disclose groups of countries presenting analogies as to system, development level, interdependence and relative autonomy, articulation and disarticulation. We could then try to identify a typology by levels of the set of systems, using this to classify action legels, detecting corresponding nodes of interdependence to try to dominate both education and technology together at the level concerned; it is upon these key points that the development of general and specific methods and instruments should be considered.

This work is on a huge scale, but it is commensurate with the problems, dangers and urgency of the situation.

We need to start straight away on preparing for the 21st century. Tomorrow it will be too late.

The rotations of the system cycles are unequal. Acceleration in technical progress sometimes makes it possible to perfect and launch new processes or products within three to five years. Other types of research and development require ten years or more.

A pedagogical research exercise requires from four to nine years.

If technological education curricula could be reformed over two or three years, it would begin to produce its results four or five years later. When one considers how quickly technological knowledge obsolesces, it might be fair to anticipate that after 10 or 12 years, those trained on the basis of regrouped knowledge would exercise a decisive influence on the whole movement of technology creation and transfer. To bring about a really deep-seated change in the system would require about twenty years in all.

To establish a technology typology, general organology and mechanology at an operational level would be an undertaking comparable in magnitude to the classification of scientific and technological knowledge (133). Bearing in mind that the latter took eight years, it might be fair to anticipate that work on it would be sufficiently advanced after ten years to begin to furnish elements of

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(183) Refers to the Unesco "Spines" thesaurus - see note 122

technical culture and inputs to the knowledge model. In 20-25 years it could exert a deep-seated action.

Modification in the cultural model take still longer to come about, but in 20 to 30 years many countries have effected a radical silent revolution in manners, and demography. In an era of widespread intercommunication, the trend is to an acceleration in cultural change.

We have only one generation between us and the year 2000. In the heavy industries, this corresponds to two rotations of fixed capital, sometimes less. This means that out scope for influencing the production structure is limited and we should not let it go by default.

The constitution of a scientific and technological infrastructure in the developing country has been one aim of aid policy for quarter of a century fo international institutions and UNESCO in particular.

While the results have been far from negligible, the developing countries are not on the whole sources of scientific information and technological innovations, and their scientific systems remain "a-structured", "a-functional" to varying degrees and not reproducible.

A policy to strengthen the scientific and technical infrastructure of the developing countries is a necessary but not a sufficient condition for scientific and technological development.

One of the essential reasons why this policy has not been as successful as has been hoped is that its local deployment is confined to the narrow space left by technology imports.

The local scientific and technological infrastructure has been marginalised in the decision and selection process for these imports. The present international technology transfer system has, in the main, inhibiting and negative consequences for local R&D.

If national scientific and technological resources are to be put to work then, one condition is that technology imports be regulated, and this requires introducing mechanisms of a non-bureaucratic kind.

Experience (184) shows that it is enough to insert the scientific and technical infrastructure into the process of critically analysing technological alternatives for timely R&D projects to emerge.

Therefore it is not enough to hope, as all the international bodies now do, that an increase in local research and innovations will produce appropriate technologies. These cannot be expected to fall from heaven. They require networks in which demands can be formulated, articulated in organised mechanisms for regulating imports, formulating technological projects, and projects for research and development (9).

These problems are no longer to be answered by general declarations, but by setting up specific national mechanisms.

A scientific and technological potential in human resources exists in a highly unequal but not negligible extent among the developing countries. The mobilisation of such potential forms one of the decisional variables for their respective governments.

Which substantial progress could be achieved between now and the end of this century, we should nevertheless look realistically at the prospects.

There is no question whatever that owing to the present lack of structure, delays and hazards in local scientific and technical research, its contribution is bound to remain limited between now and the year 2000. As one Unesco publication quite rightly points out (135), the overall objective adopted in March 1975 at the Second General Conference of the United Nations Industrial Development Organisation (UNIDO) setting the share of the developing countries in world manufacturing output at less than 25 per cent"excludes a gradual maturing from within the countries themselves, which might to some extent secrete an endogenous innovation and adaptation process".

It will be necessary to draw heavily on technology transfers.

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(184) Informe final del Proyecto Piloto de transferencia de tecnologia - Mexico - OEA June, 1975.

(185) Le Monde en Devenir, op. cit. ref. 4.

The industrial relocation movement implied by this objective would have to involve, as an order of magnitude, the transfer to the developing countries, over thirty years, of the equivalent to the present industrial potential of the advanced countries, or the transfer of twice as much world industry as existed arount 1960 (186).

A movement on this scale, already starting as multinationals have been internationalising their production over a fairly short historical period, calls even more urgently for a drastic revision in technological training programmes.

Ultra-specialisation and narrow forms of knowledge are a blind alley, from which the developing countries must extricate themselves as quickly as possible. Regrouping of knowledge, shortening of cycles are the pre-requisites for a greater degree of "all-round" capability, a pluri-sectoral utilisation of the country's technical workforce. If the recipients of technology transfer are to dominate the process, they will need a new type of information, technical, economic and commercial, large-scale training in new technology assessment approaches. New instruments and new praxeologies will be needed.

One of the "by-products" of research into technology typologies could be the establishment of technology ripple-effect networks. A technology A makes it possible to move on to a technology B, while in combination with technology C, the route is open to technologies D, E, F, G etc. In the first stages such graphs could take the simplified form of large-scale maps or technological itineraries. These would form one of the first instruments enabling the developing countries to determine their technological objectives in full knowledge of what they are doing. It would be a way of no longer considering technology as merely a datum in development, but as one of the variables. In five years the first maps could be drawn up. Smaller scale maps could then follow, depending on the progress in working out technology typologies. For all who are familiar with international institutions these ideas, projects and time-scales, may arouse some degree of scepticism...!

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(186) Calculated on the basis of a 3.5 per cent growth rate annually in the developed countries.

But it is only possible to formulate instruments and praxeologies of the necessary scope by painting a broad canvas and taking a very long view.

The incrementalism which has dominated the United Nations system of the last thirty years has been thought to demonstrate its effectivness through countless short term activities. But this, too, engenders an institutional "fragmentation" which can today be discerned as an obstacle to long-term efficiency, for which integrated programmes are needed. (187)

It must be recognised that given the formidable contradictions for society in its two vital spheres of education and technology, the exceptionally large-scale industrial re-deployment envisaged, the problem area of the new economic order, the segmented and disarticulated programmes of the United Nations bodies are no longer adapted to the problems of the end of this century.

Effectiveness means taking the long view, working out methodologies and powerful instruments with which to act in the service of mankind. (188)

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(187) " A new United Nations structure for global economic co-operation" Report of the Group of Experts on the structure of the United Nations System.

(188) This, moreover, was the line taken by the study group for the analysis of major world problems and the potential Unesco contribution to their solution - See also "Le Monde en devenir", reference 4.

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RESEARCH REPORT No. 42: This study is an attempt at the construction of a model of the relationships between the educational and technological systems. Analysis of the characteristics of the two systems has revealed various types of relationships. The general aim was to ascertain whether the combination of the field of analysis with technology is a basic condition for planning: and therefore to define a common approach to the problems of planning education and training in relation to technological progress.

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